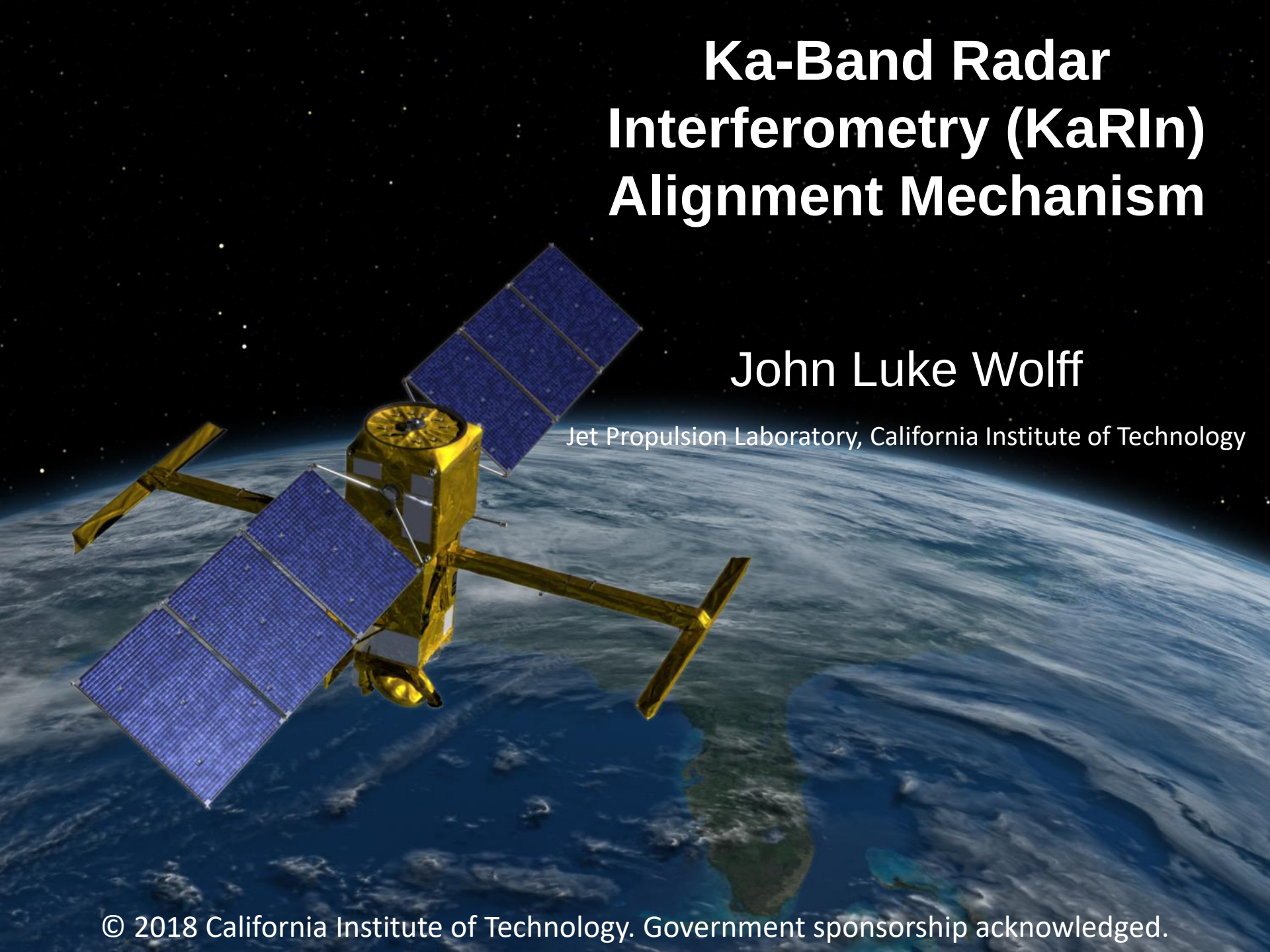
Ka-Band Radar Interferometry (KaRIn) Alignment Mechanism



John Luke Wolff

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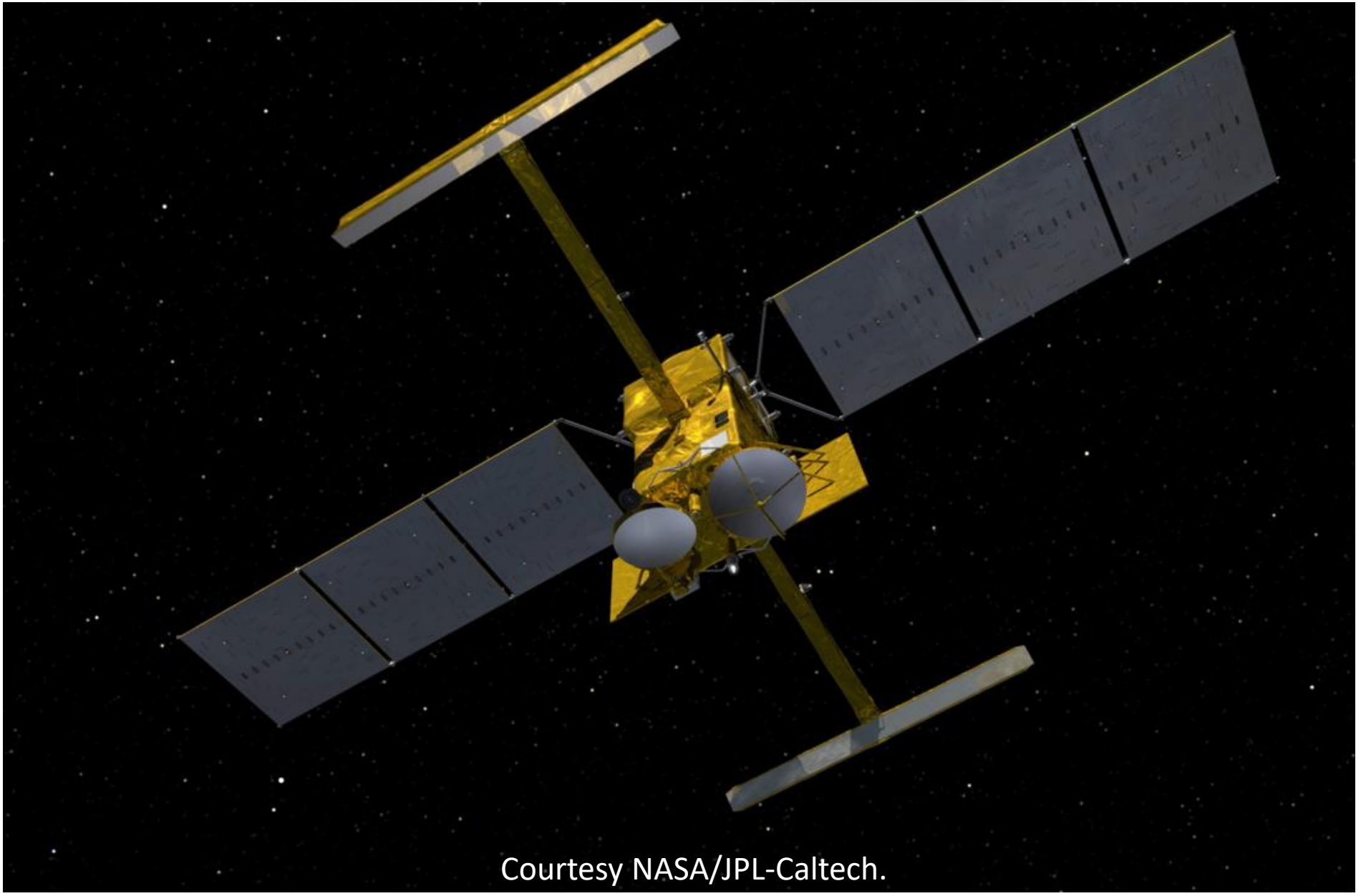
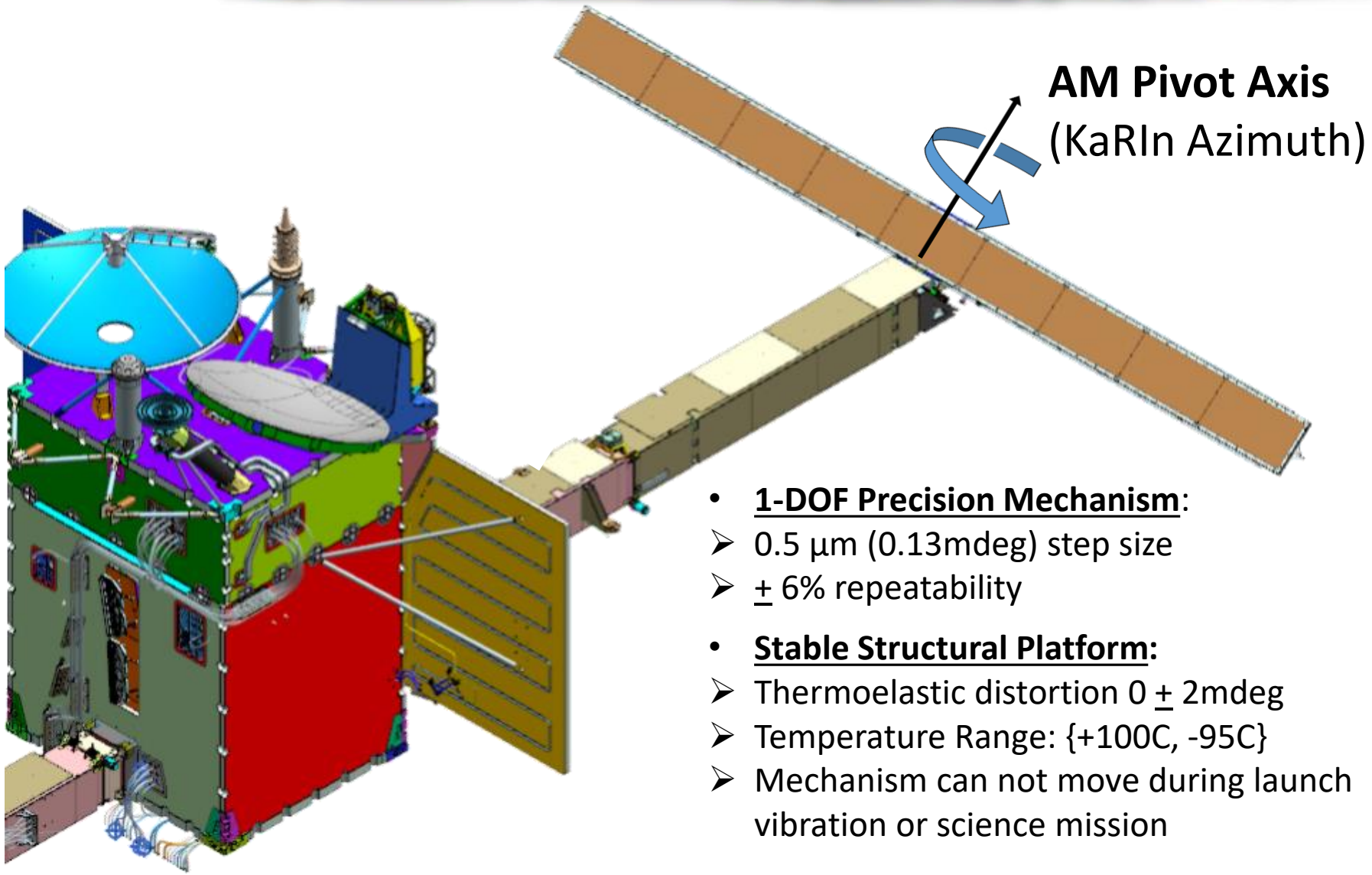
KaRIn Instrument Overview



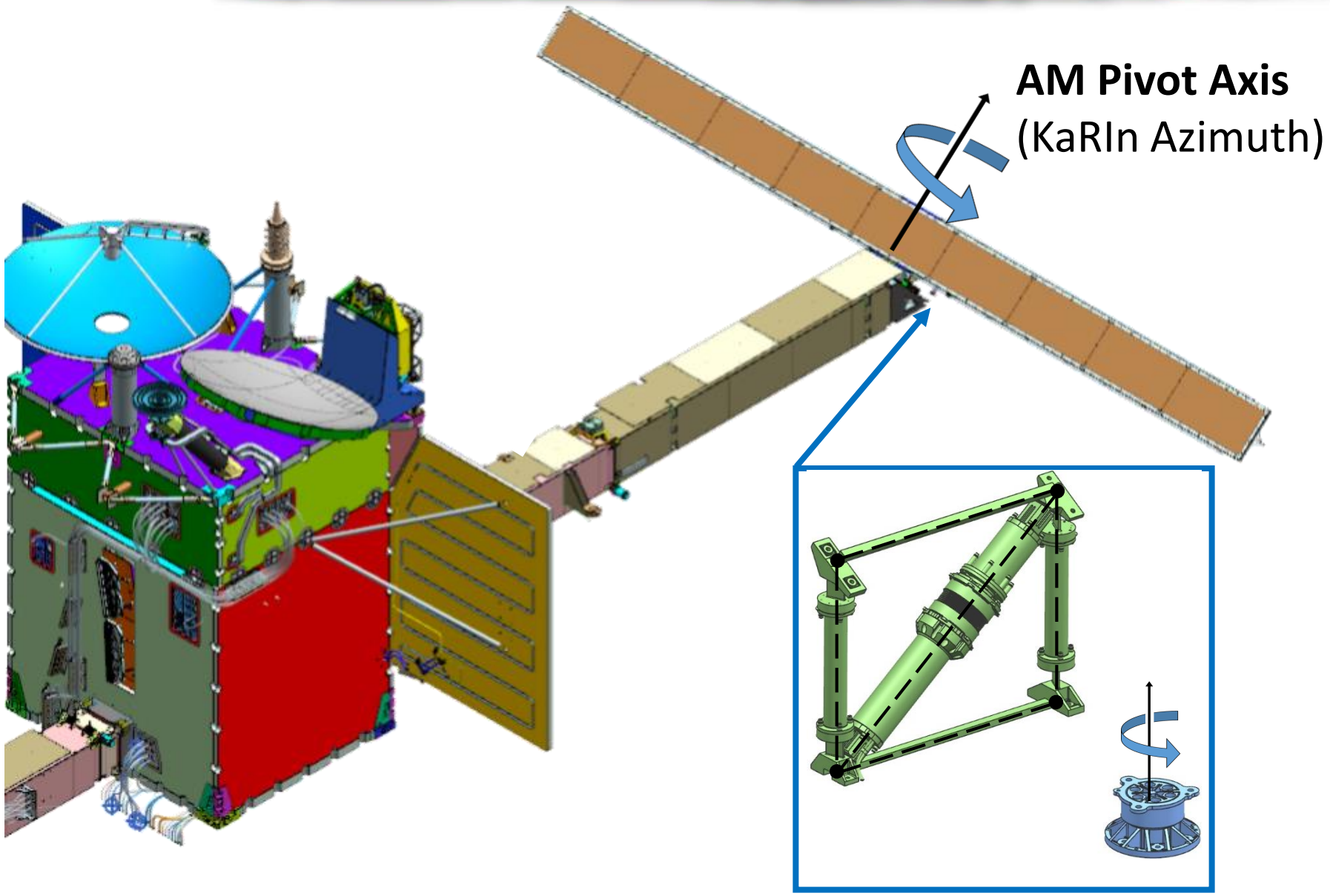
Courtesy NASA/JPL-Caltech.

KaRIn Alignment Mechanism Overview

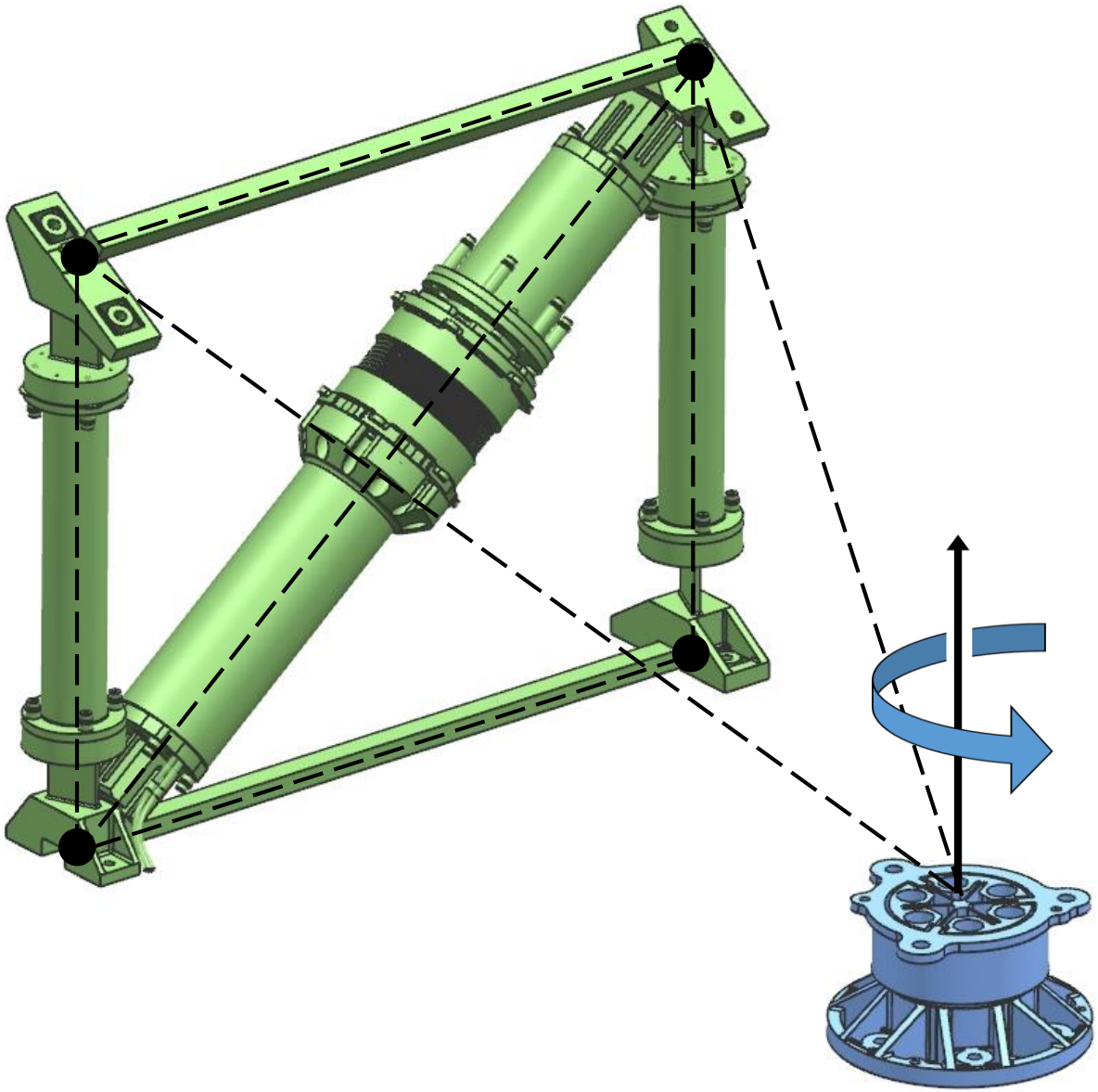


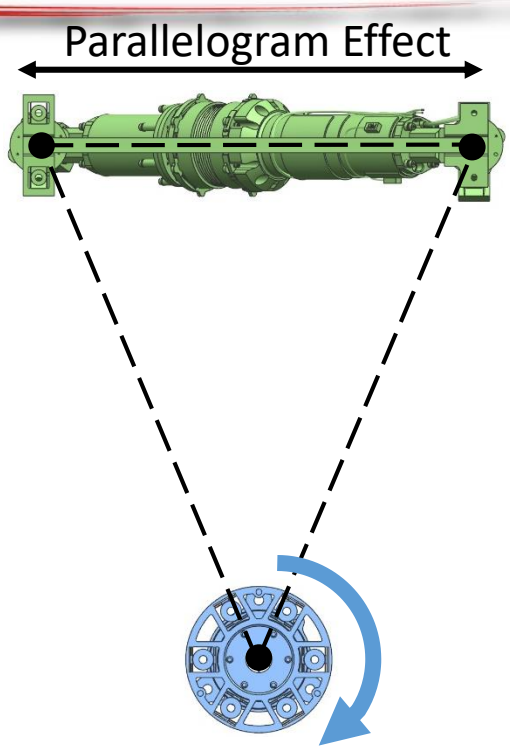
- **1-DOF Precision Mechanism**:
  - 0.5 µm (0.13mdeg) step size
  - ± 6% repeatability
- **Stable Structural Platform:**
  - Thermoelastic distortion 0 ± 2mdeg
  - Temperature Range: {+100C, -95C}
  - Mechanism can not move during launch vibration or science mission

KaRIn Alignment Mechanism Configuration

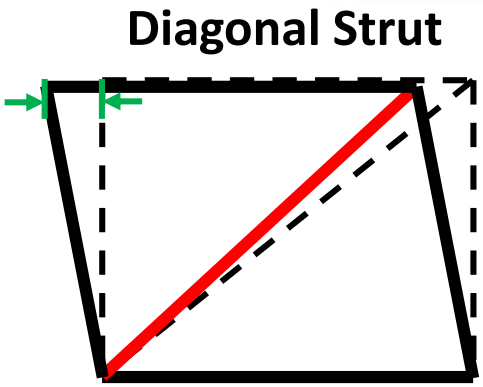


KaRIn Alignment Mechanism Kinematics

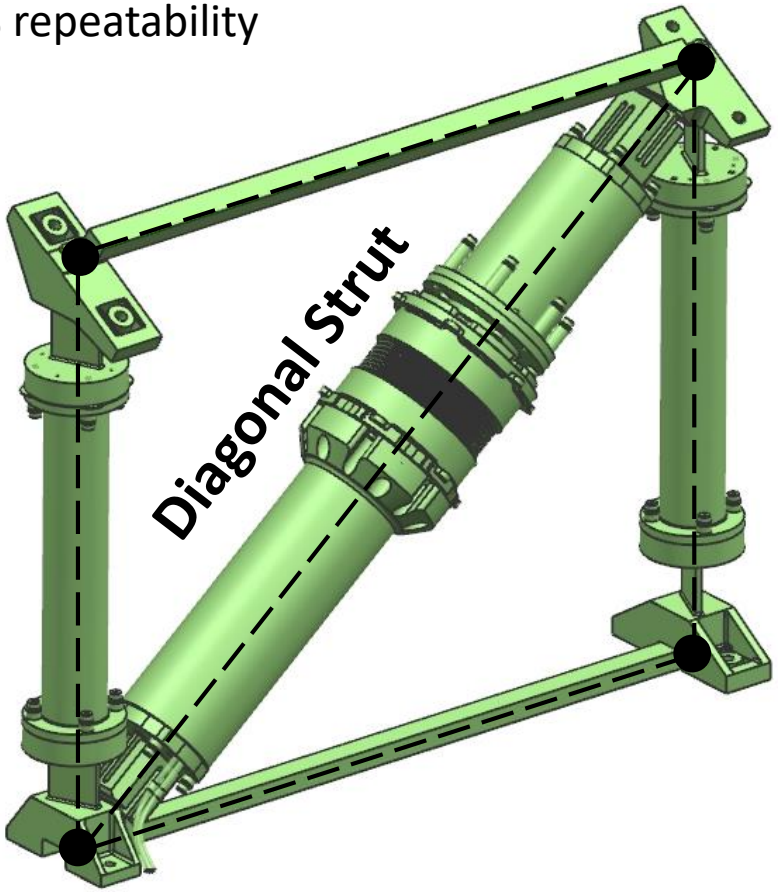


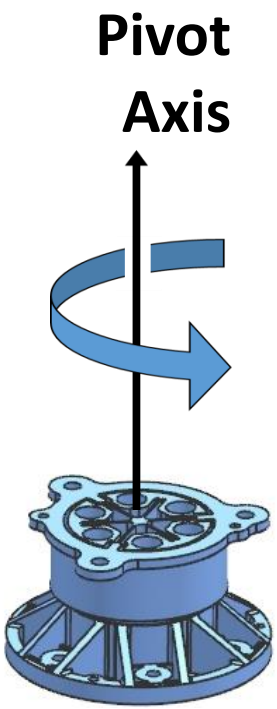


Commanded Motion Kinematics



- **1-DOF Precision Mechanism**:
  - 0.5 µm (0.13mdeg) step size
  - ± 6% repeatability

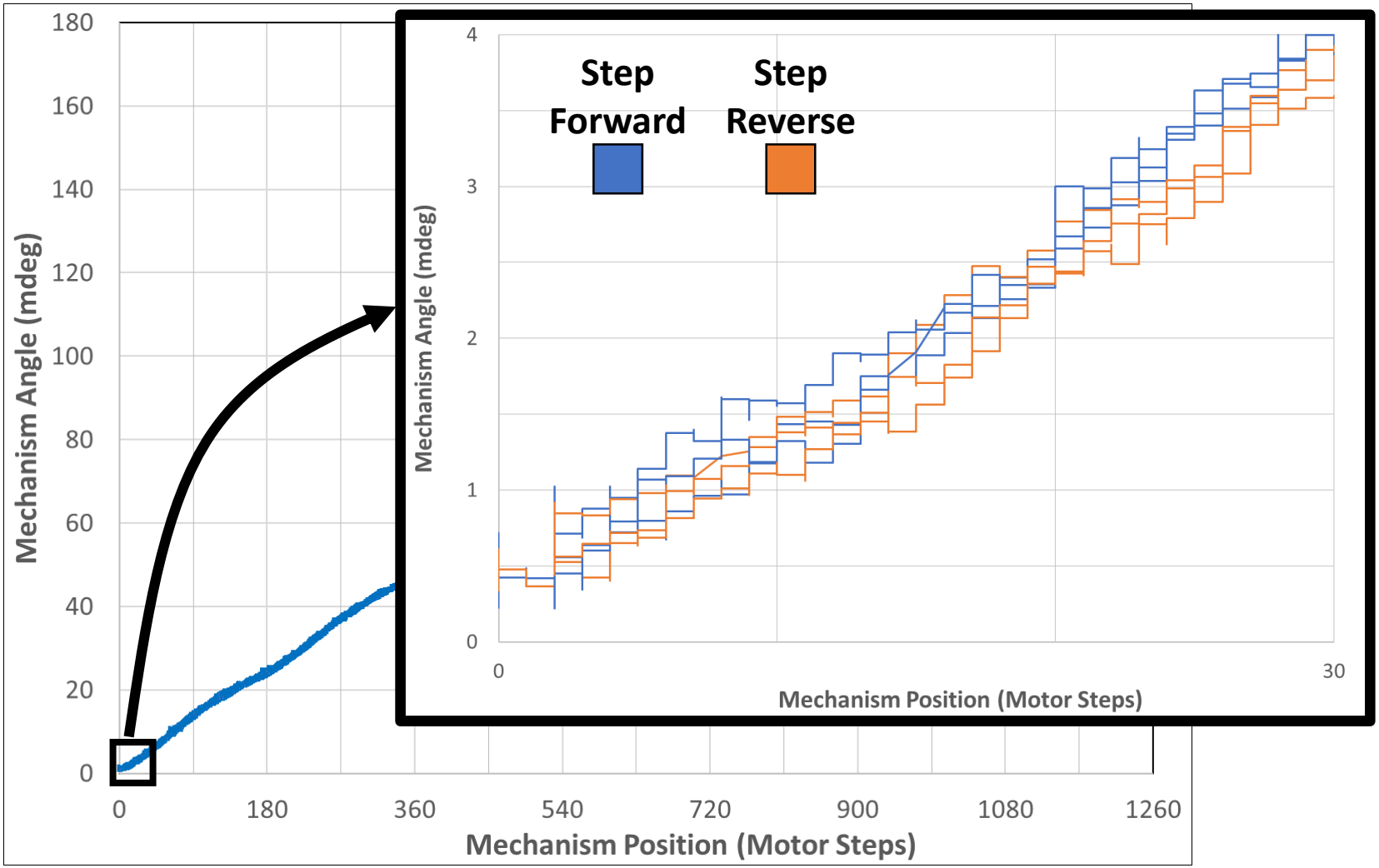




Commanded Motion Performance

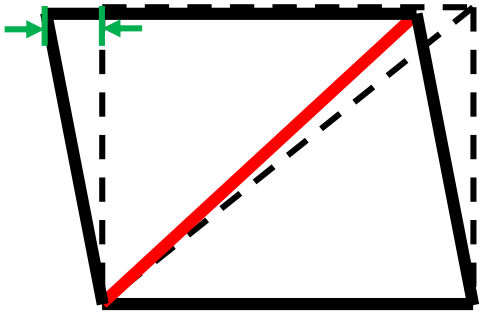
Measured four mechanism cycles both directions

- Average 0.133mdeg per step
- Absolute position within ±0.3mdeg

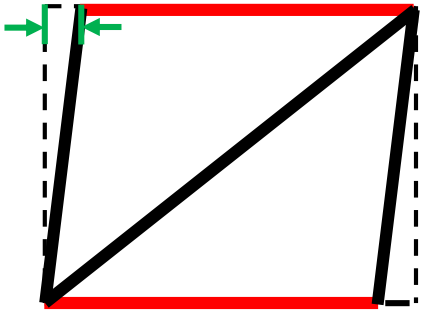


Thermoelastic Distortion Kinematics

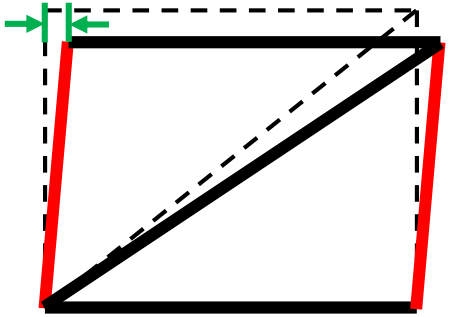
Diagonal Strut



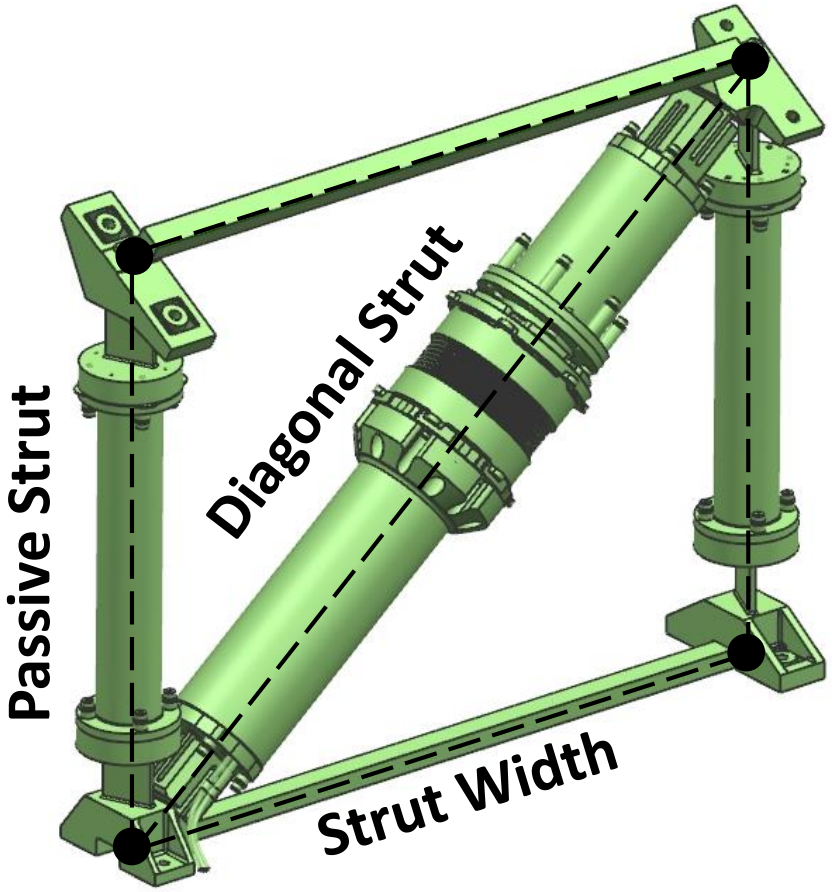
Strut Width

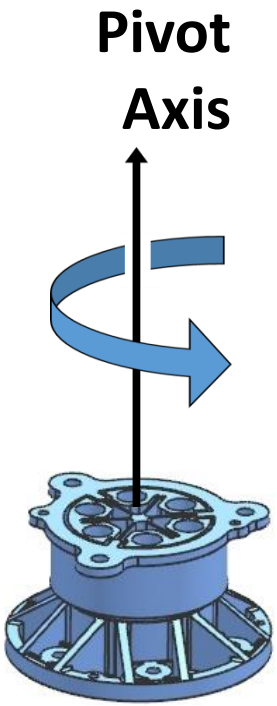


Passive Strut

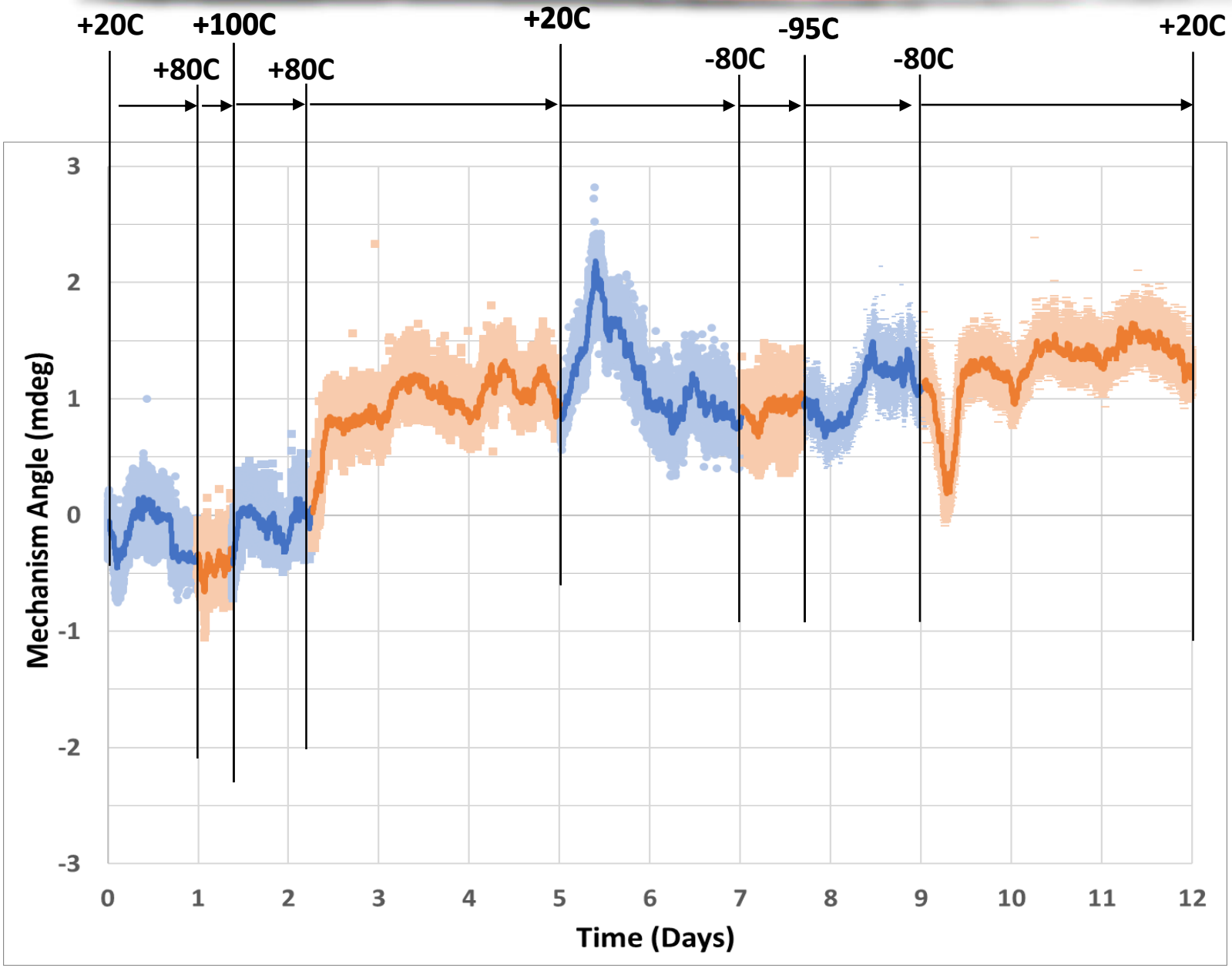


- Thermoelastic distortion 0 ± 2mdeg
- Temperature Range: {+100C, -95C}

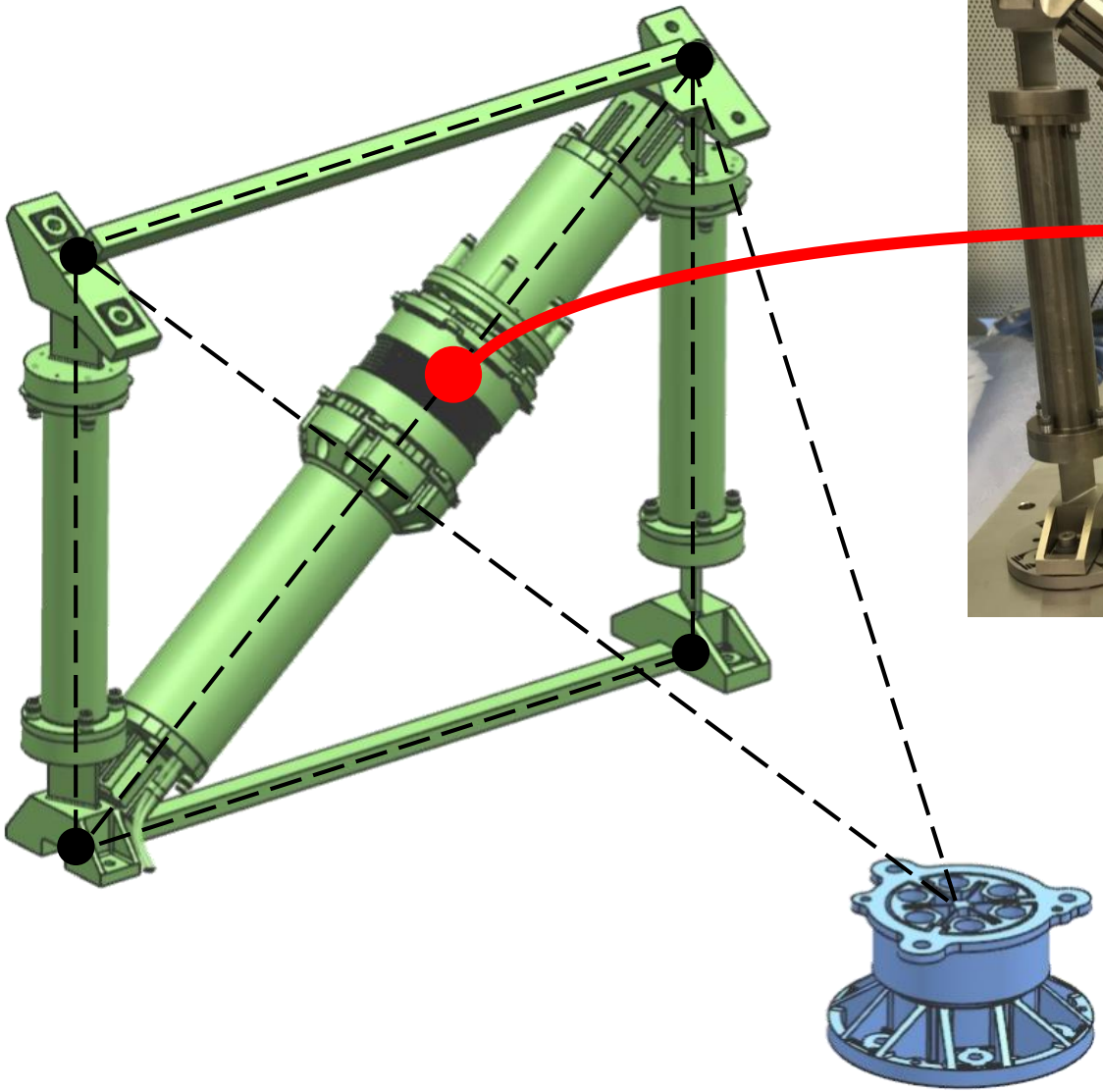


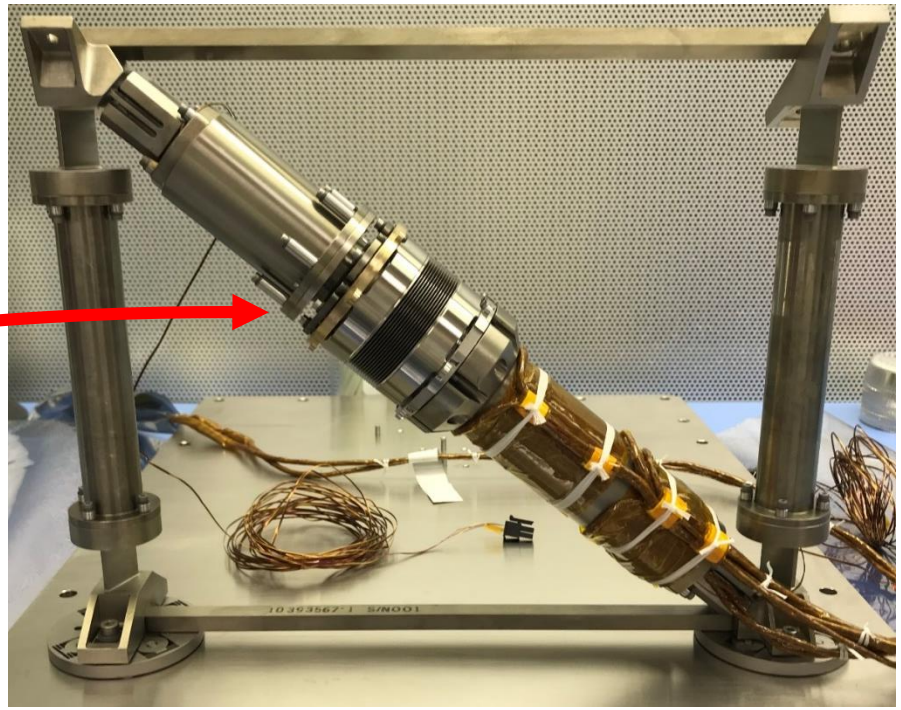


Thermoelastic Distortion Performance

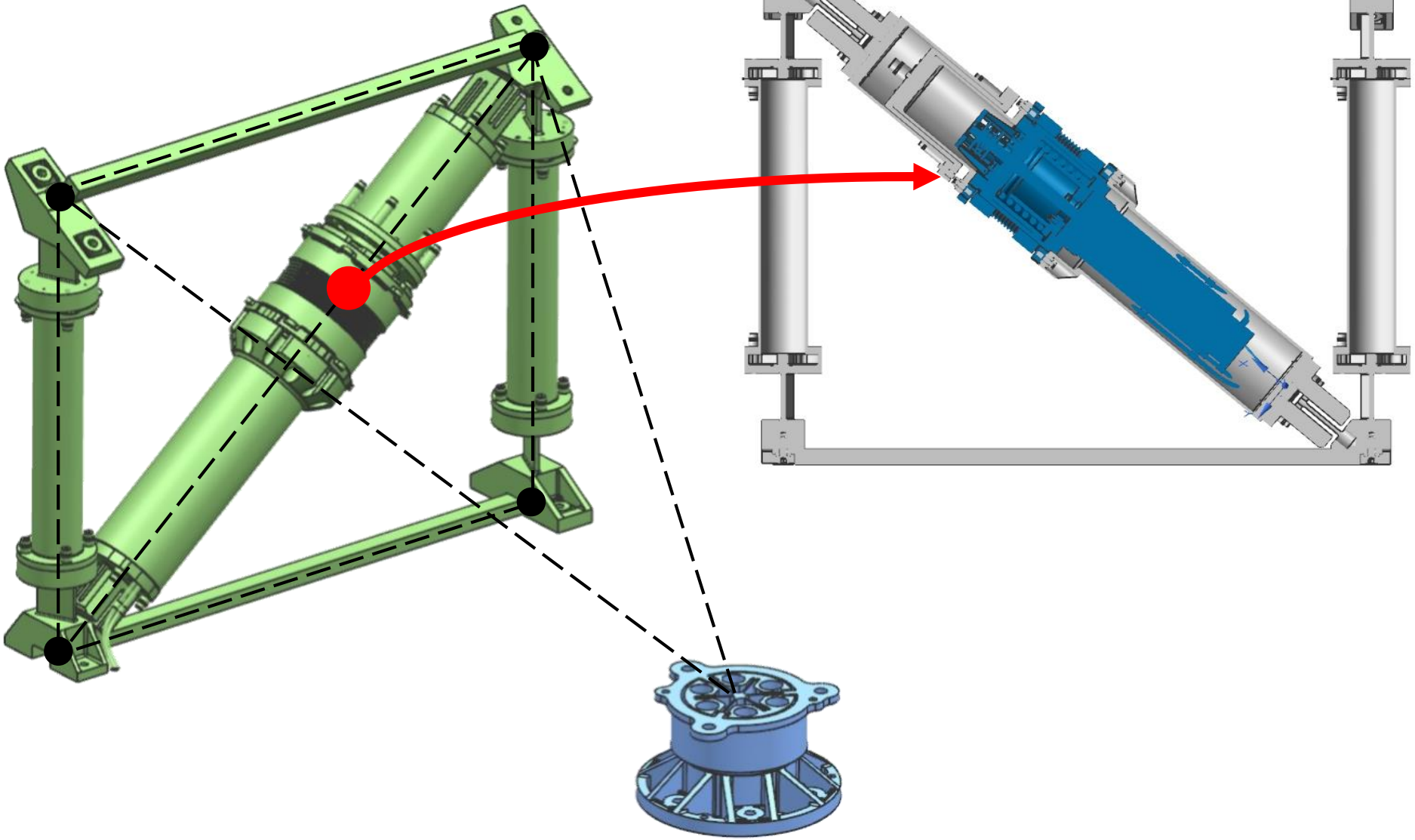


Mechanism Strut Assembly

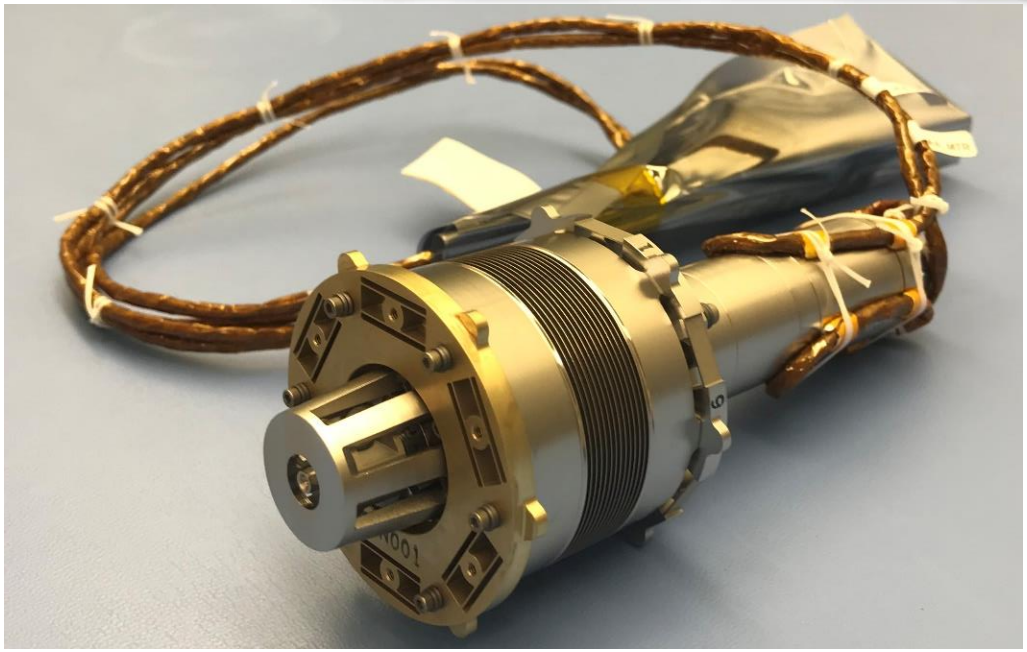


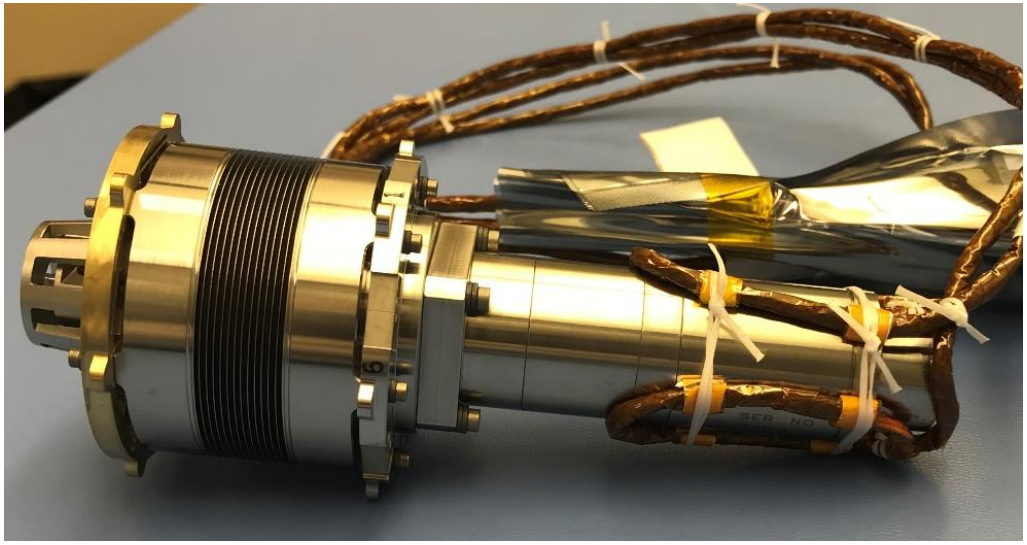


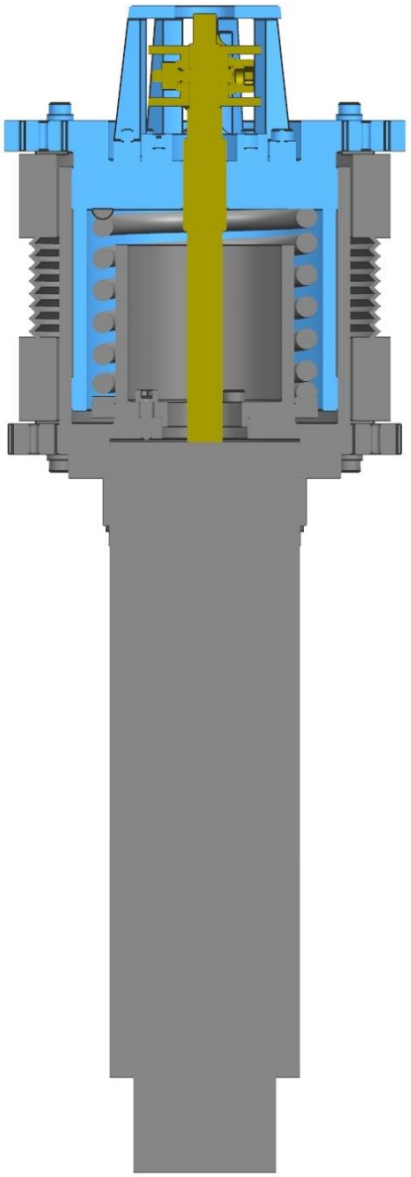
Linear Actuator Assembly Configuration (in Mechanism Strut Assembly)



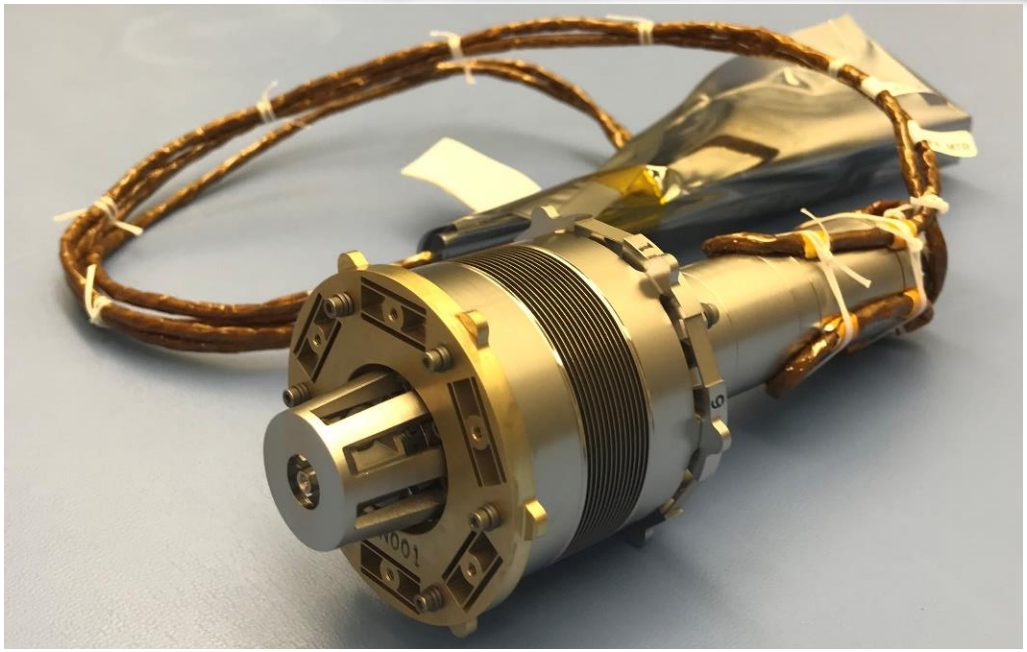
Linear Actuator Assembly Kinematics: ACME Leadscrew/Nut

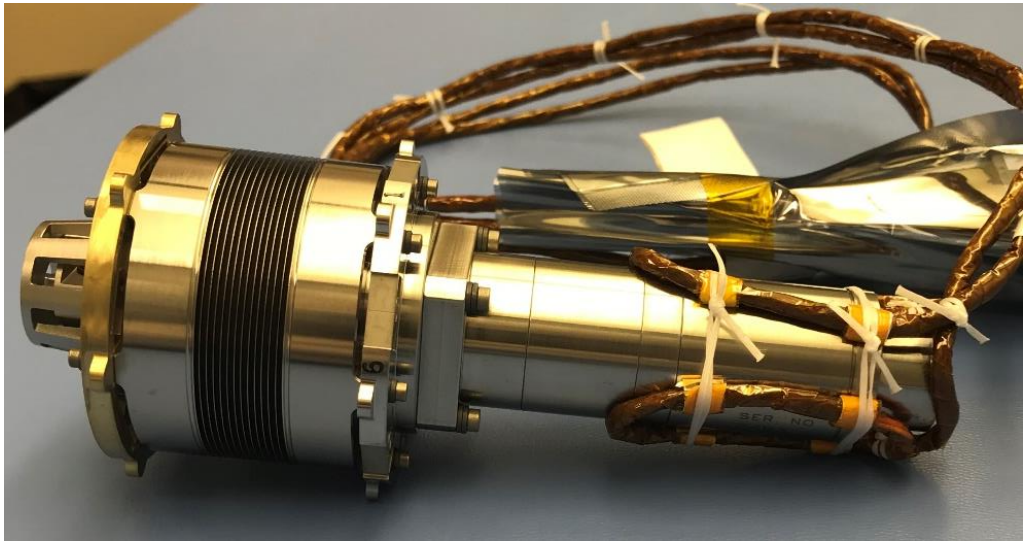


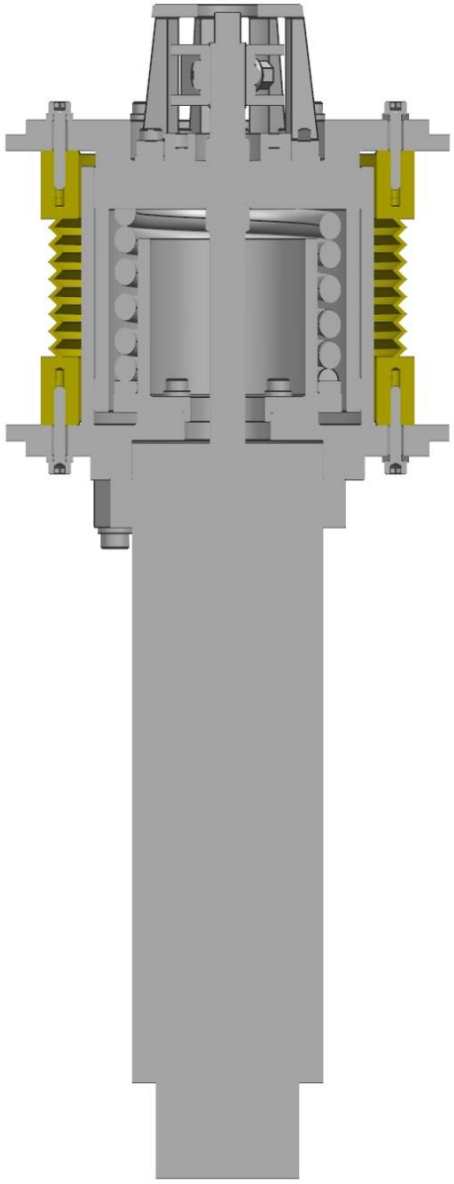




Anti-Torque Feature: Bellows Assembly

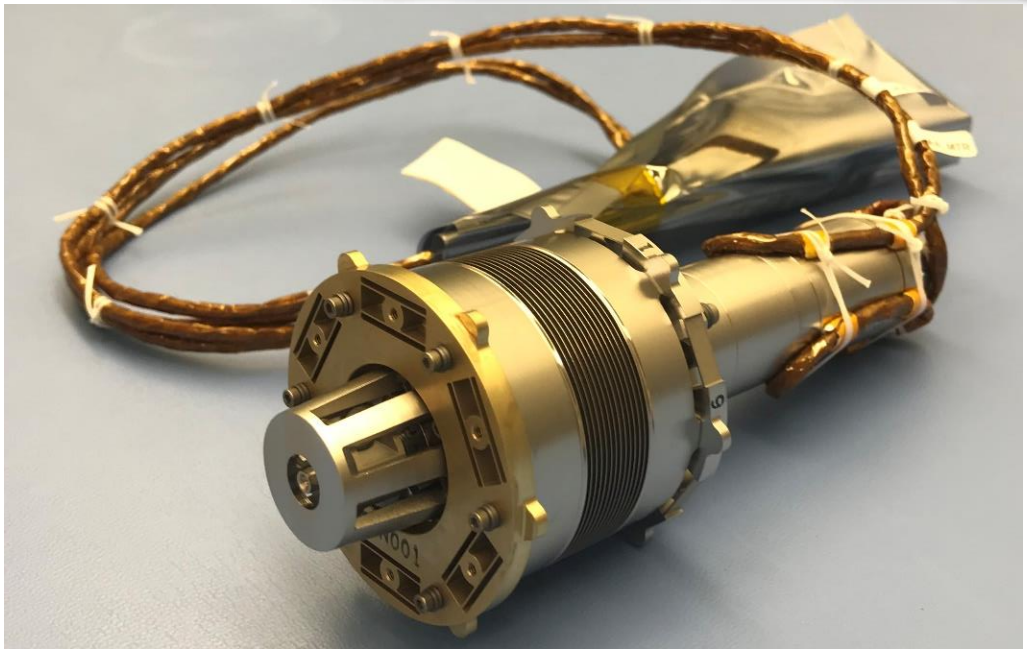


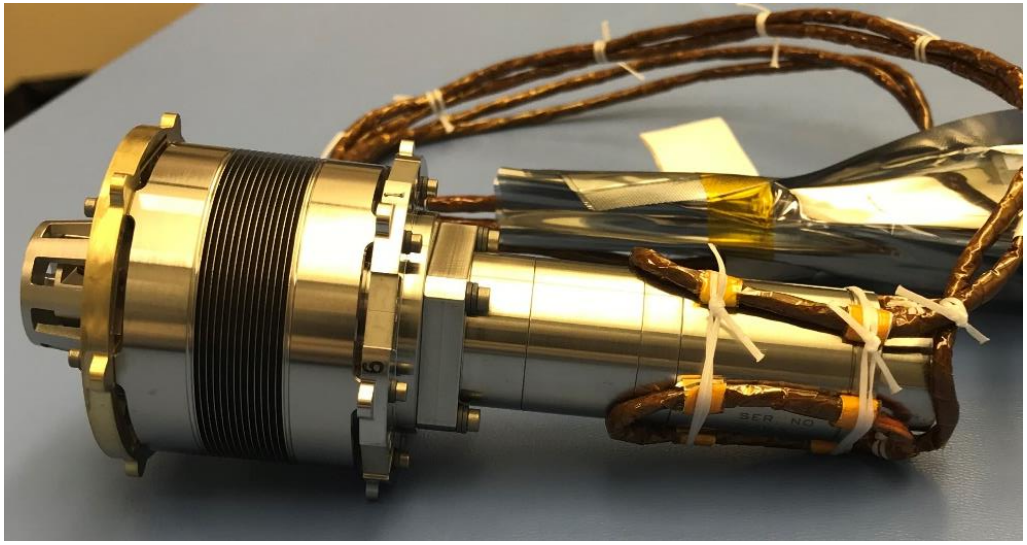


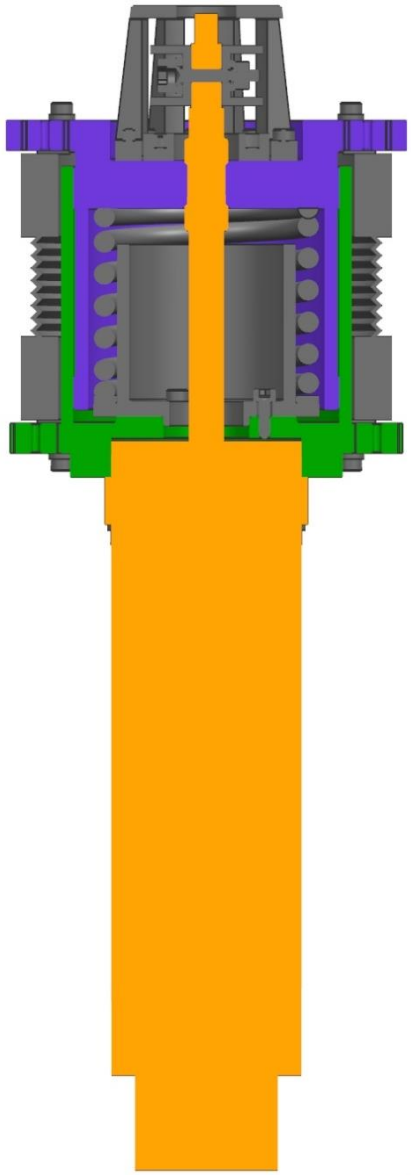


Bellows Assembly

Limit Bending Loads through Actuator: Plain, Telescoping Bearing Housings





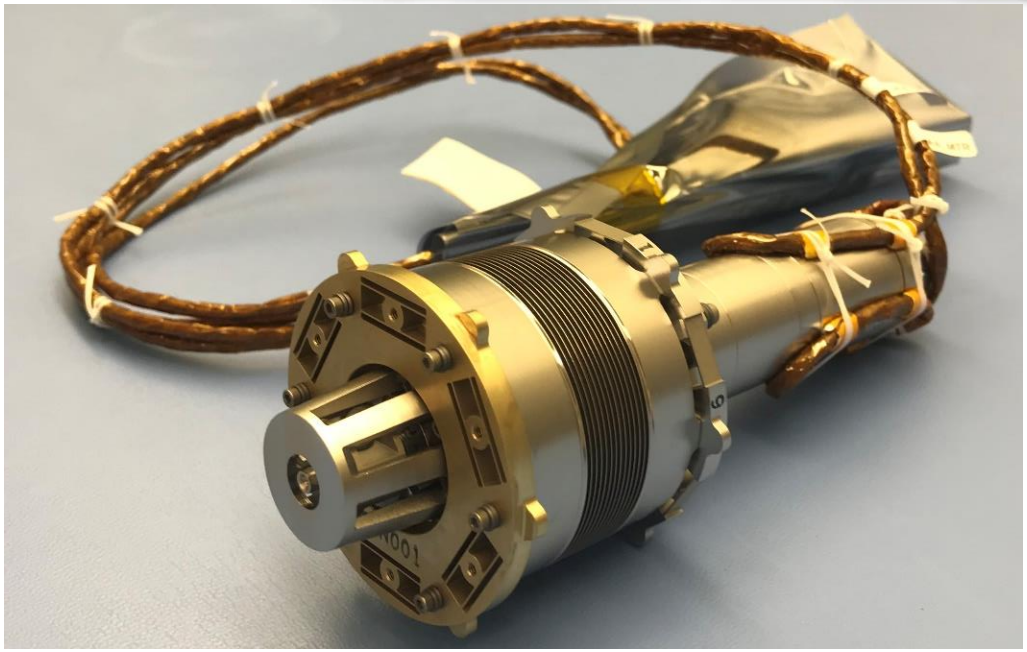


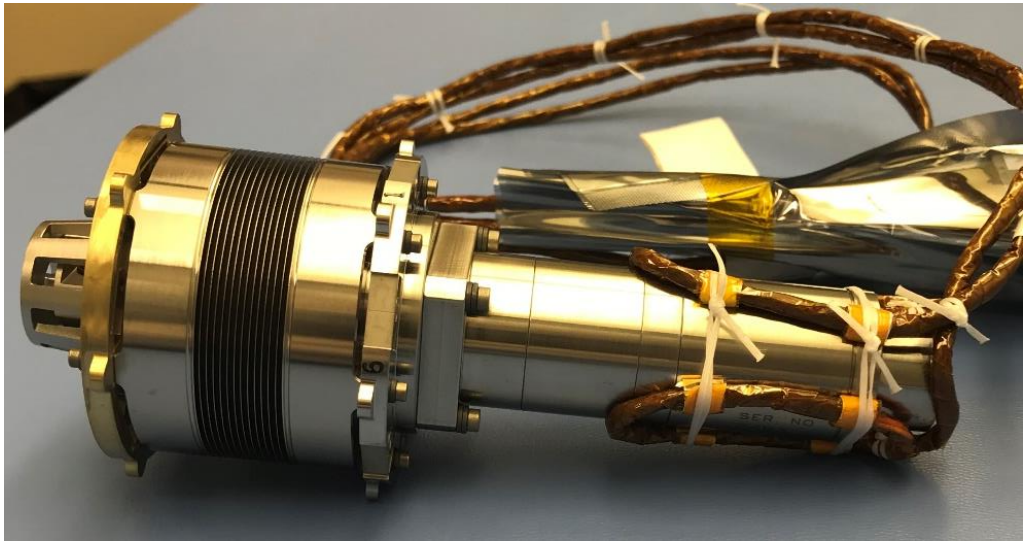
Actuator Assembly

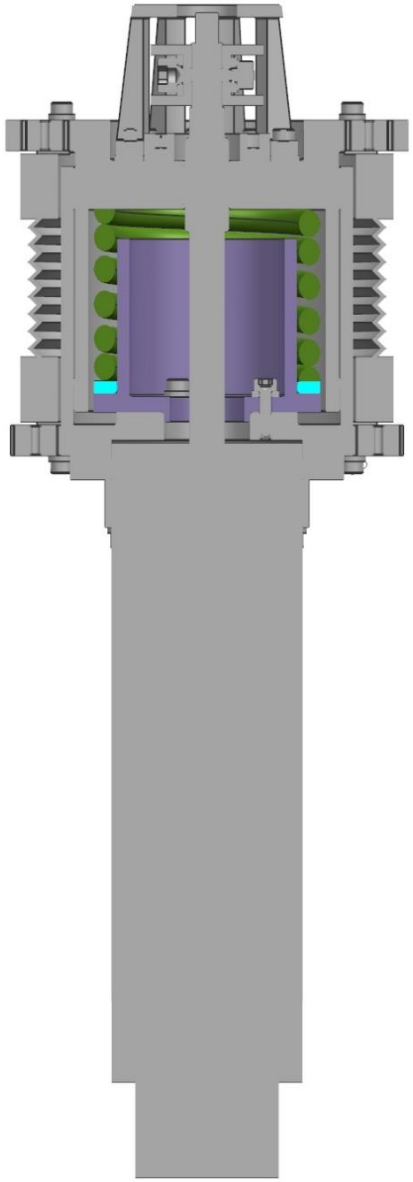
Inner Bearing Housing

Outer Bearing Housing

Minimize Backlash: Preload Mechanism for Operations



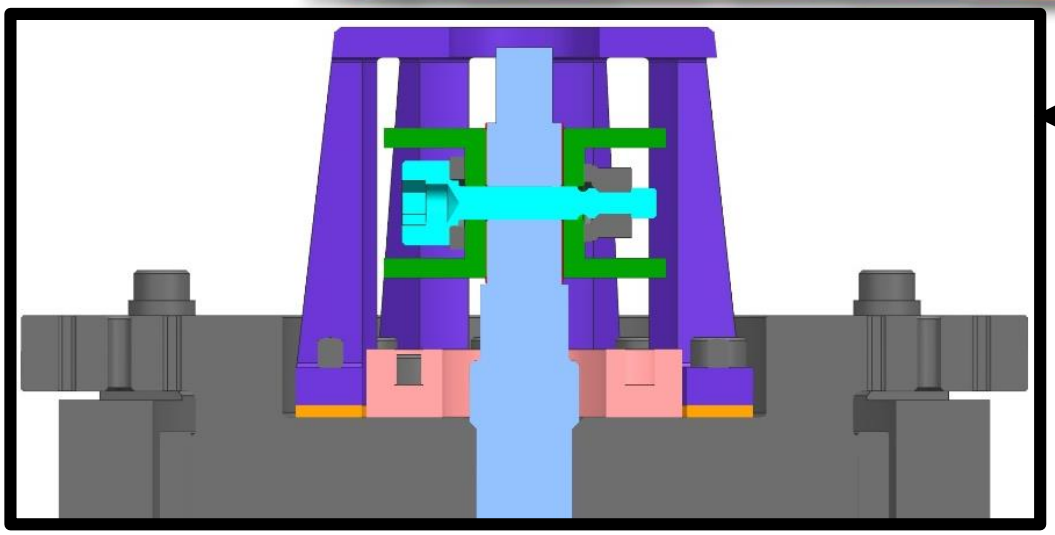


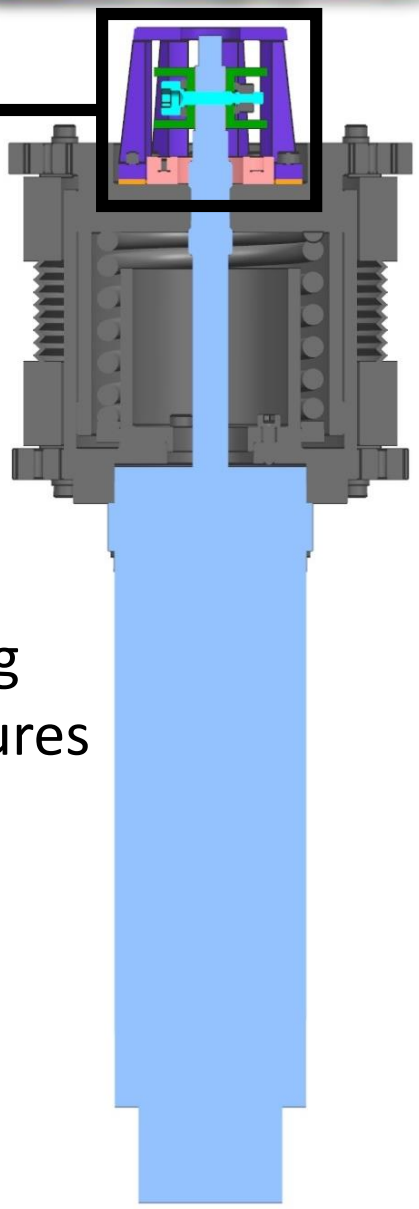


Compression Spring

Spring Guide

Limit Mechanism Travel: Non-Jamming Mechanical Hard-Stops

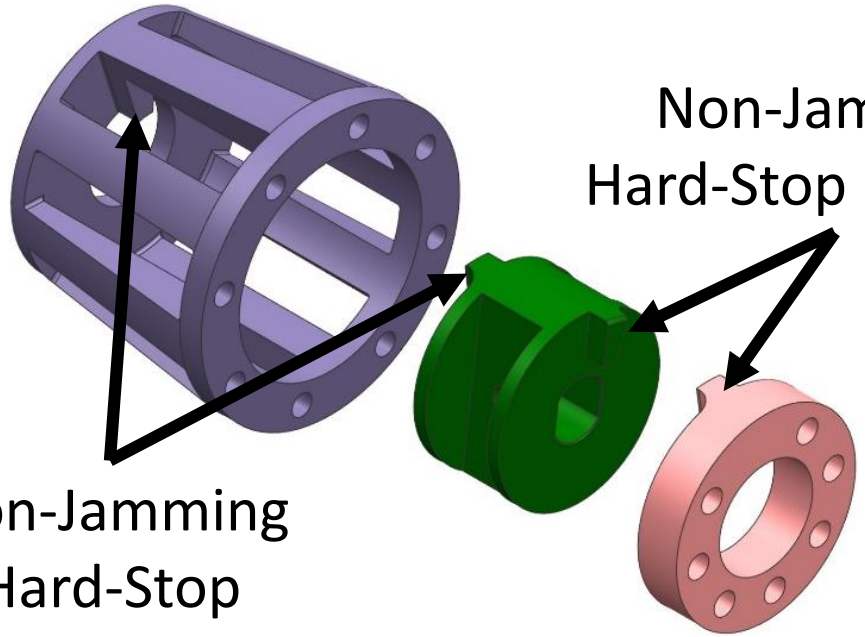




Leadscrew Hard-Stop

"Compress" Hard-Stop

"Extend" Hard-Stop

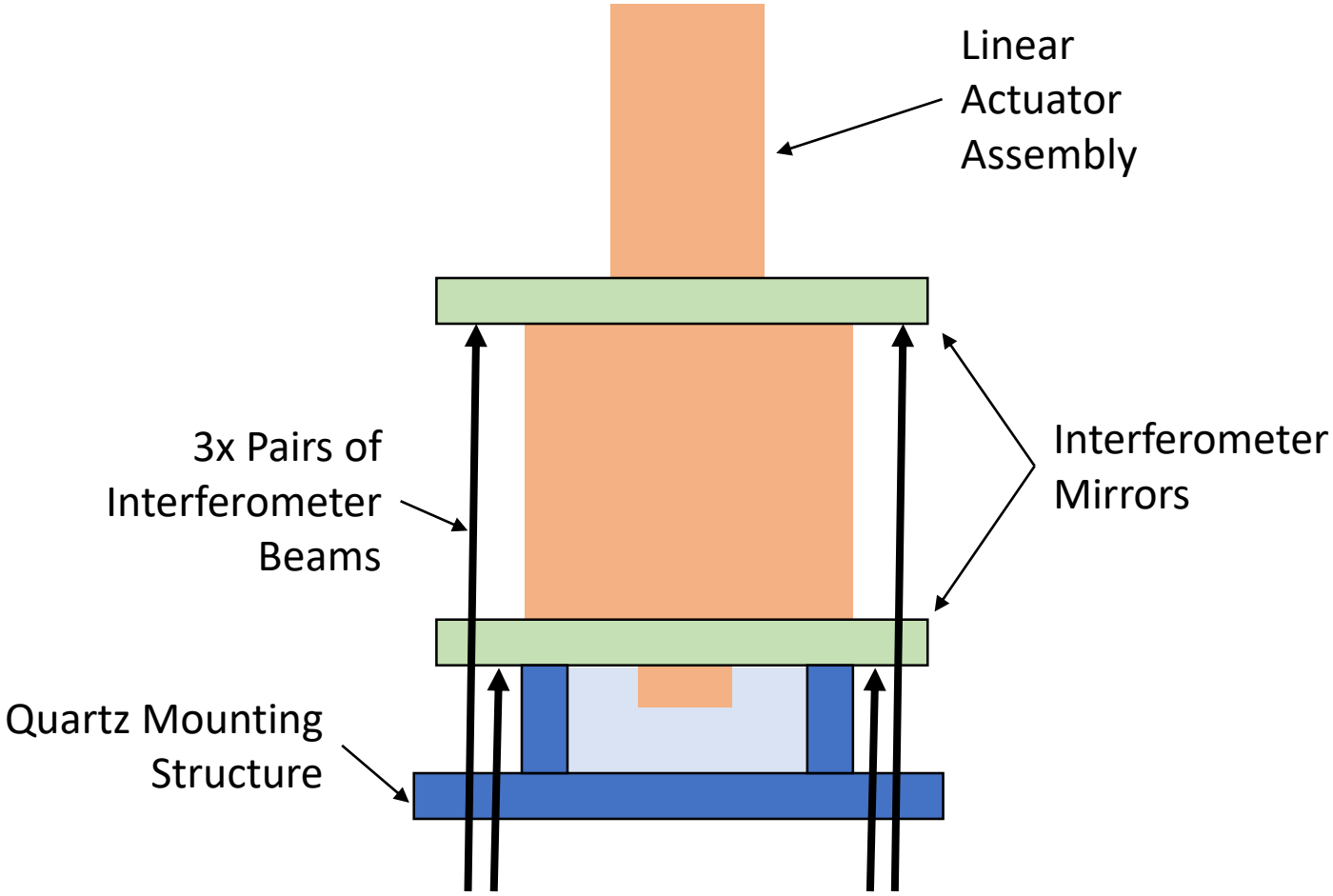


Non-Jamming Hard-Stop Features

Non-Jamming Hard-Stop Features

Linear Actuator Assembly Performance Test Setup

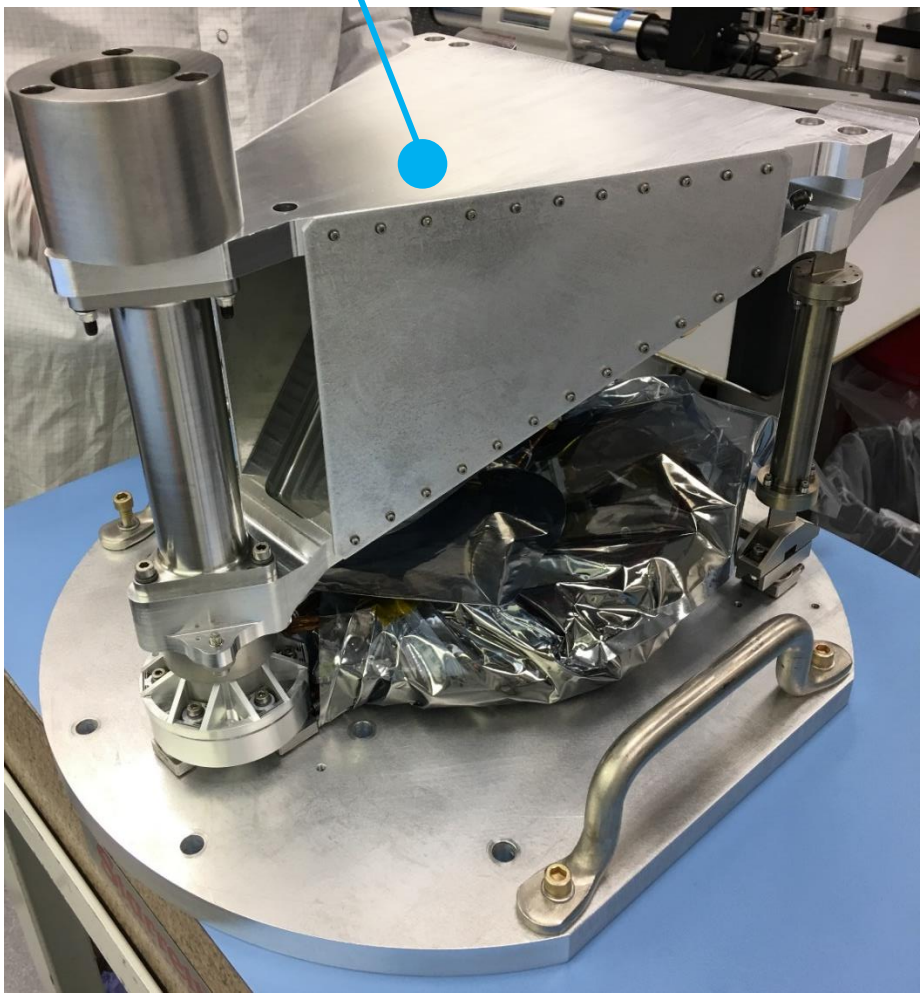
Laser interferometry per ASTM E289
(Vacuum Chamber)

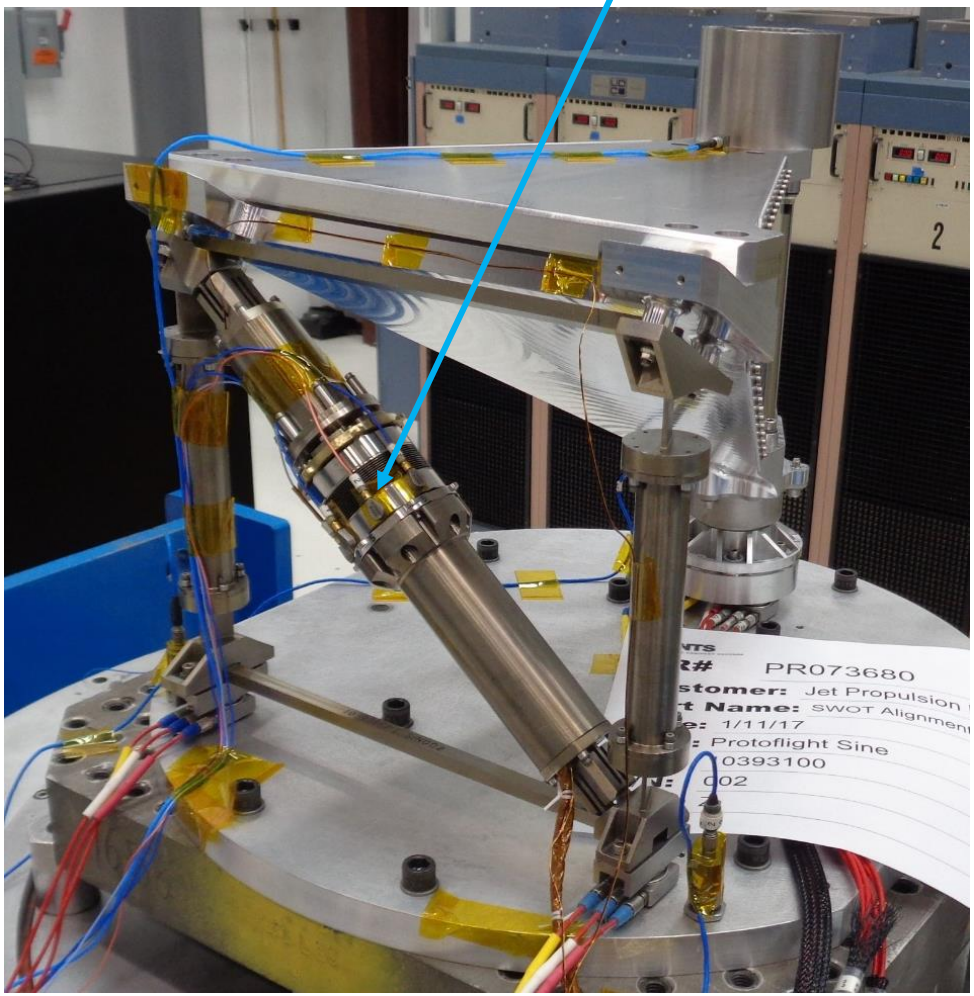


Mechanism Configured for Vibration Testing

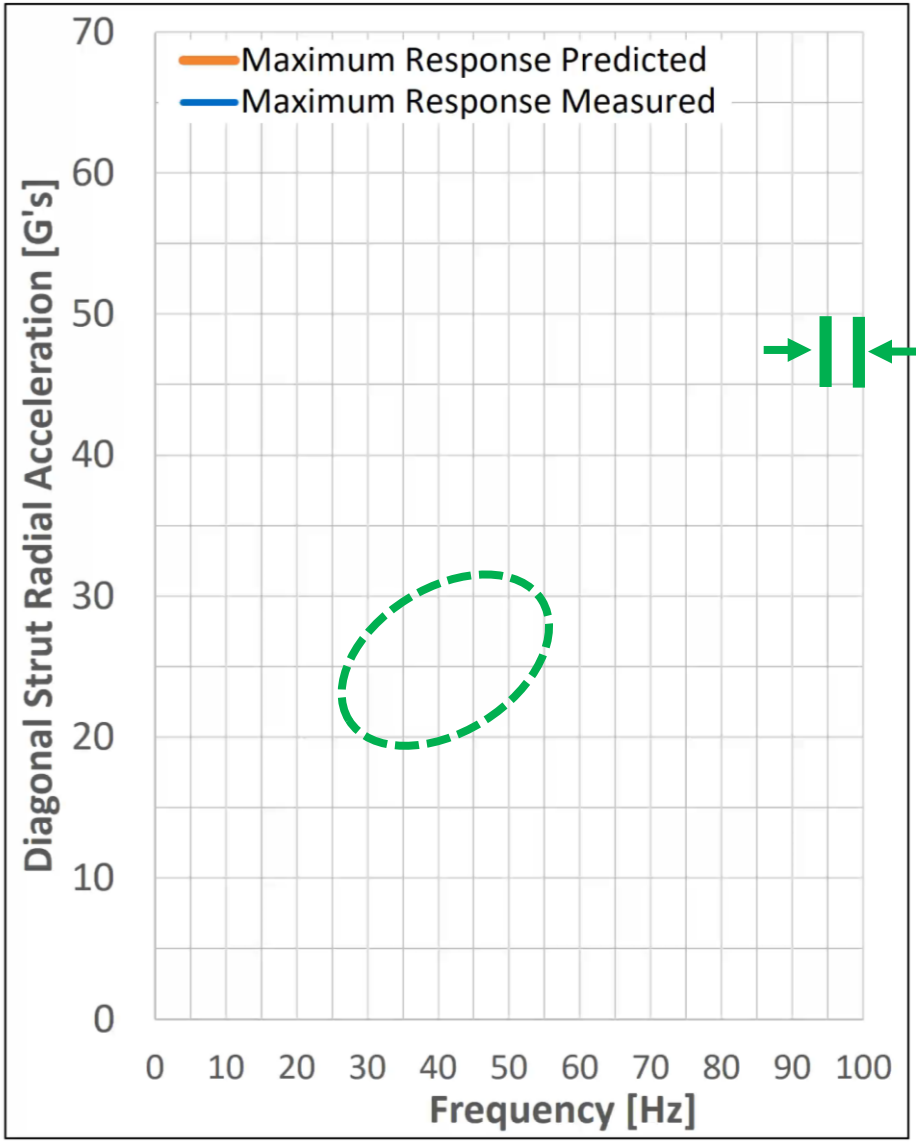
Mass Simulator:
Represent mass supported by mechanism during launch

4x Single Axis Accelerometers:
Local bending mode of diagonal strut

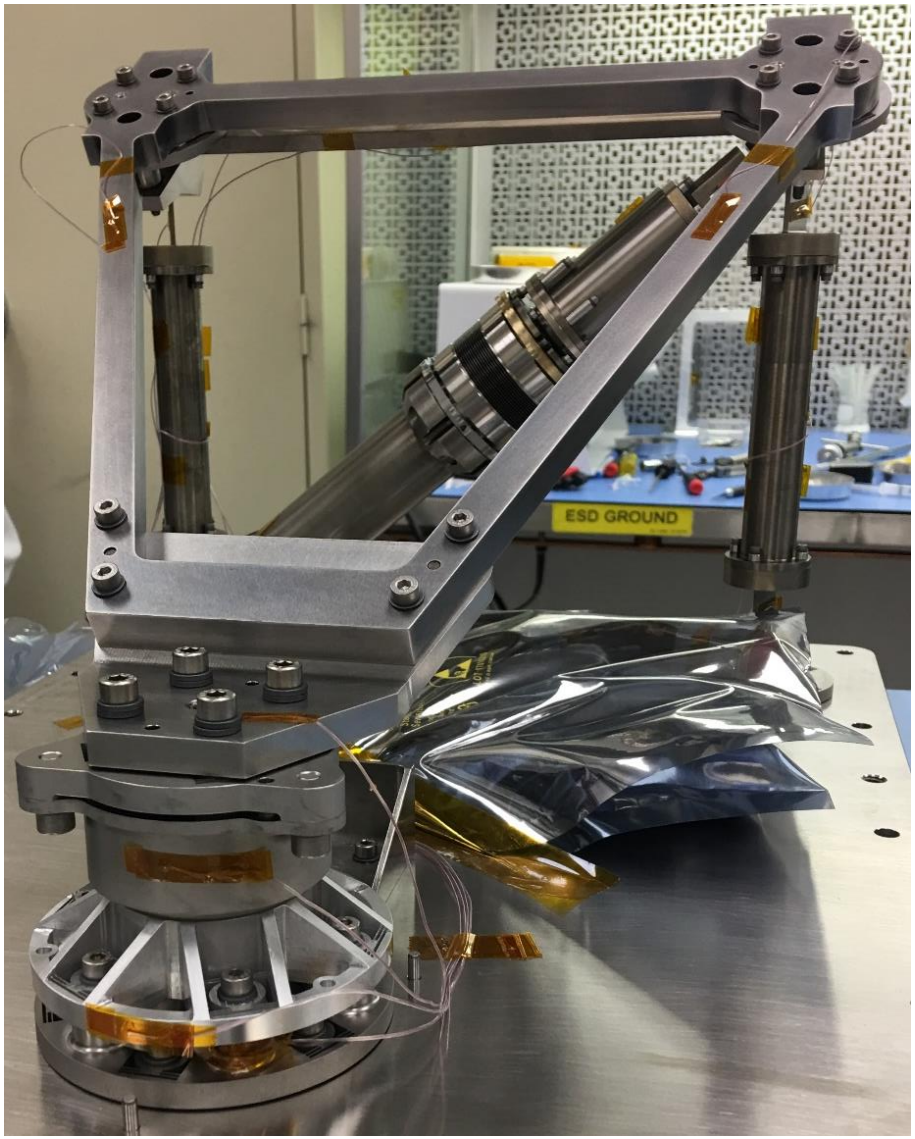


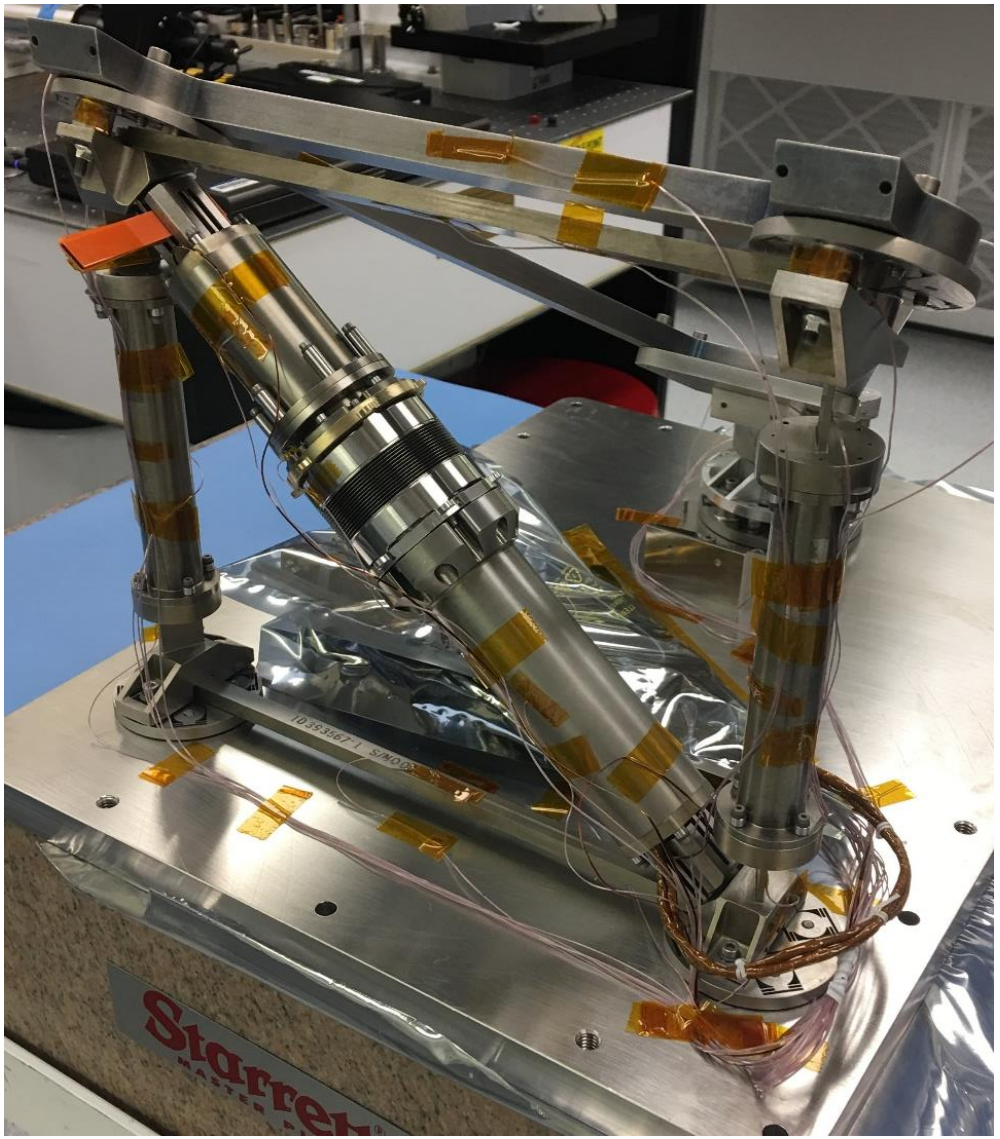


Vibration Test Results Compared to Non-Linear Contact and Gapping Finite Element Modeling



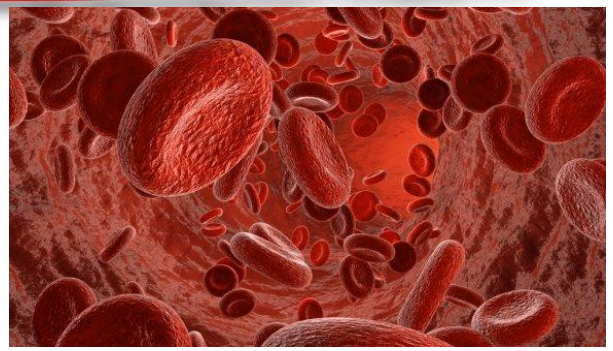
Mechanism Configured for Performance Testing in Thermal Vacuum Chamber





What is 0.5 microns? How hard could it be?

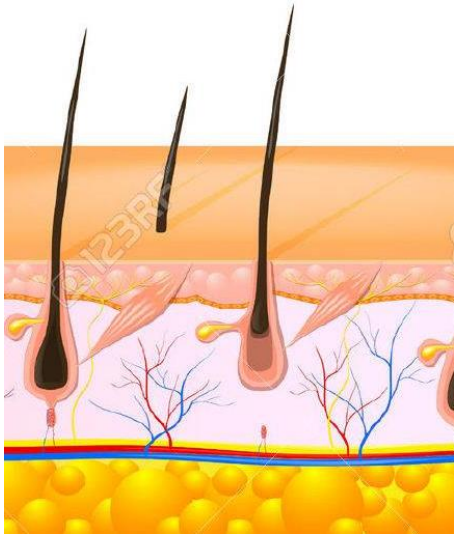
The Wavelength
of Cyan Light



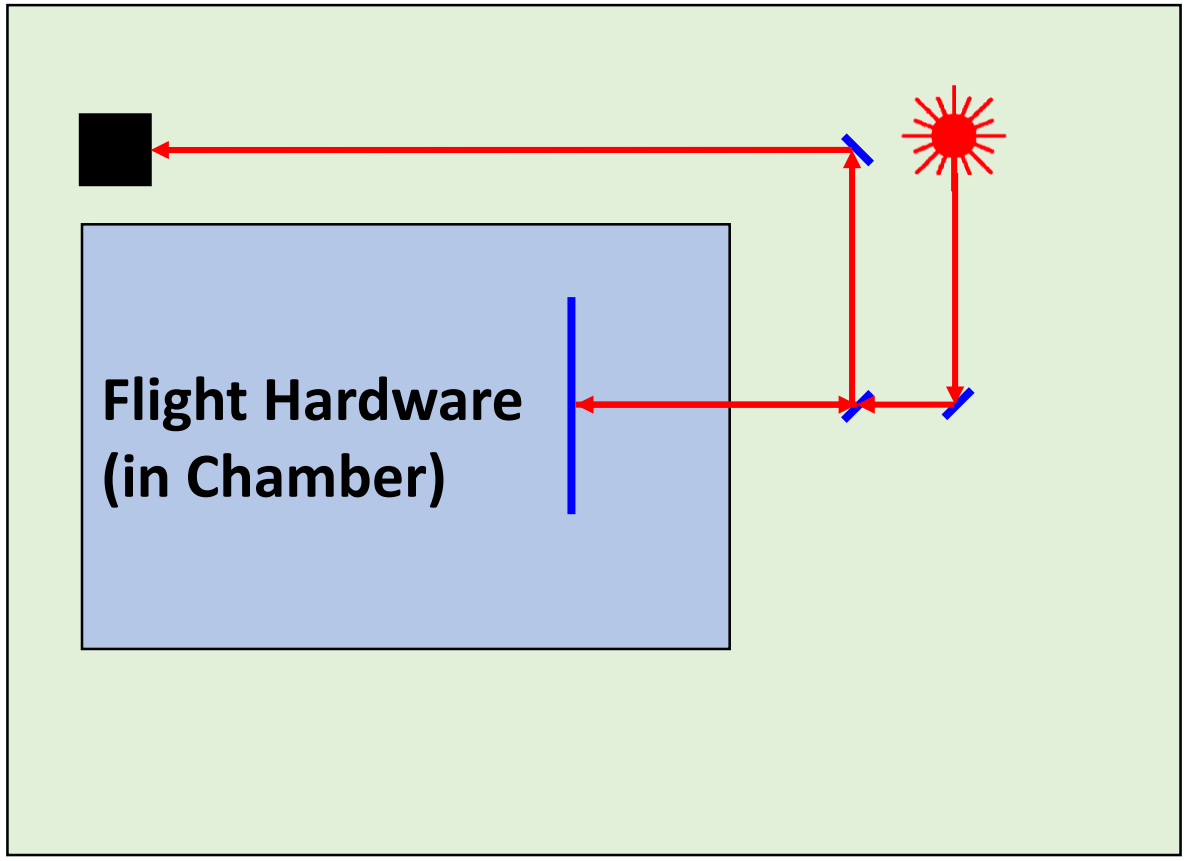
1/14th the Diameter of
Human Blood Cell

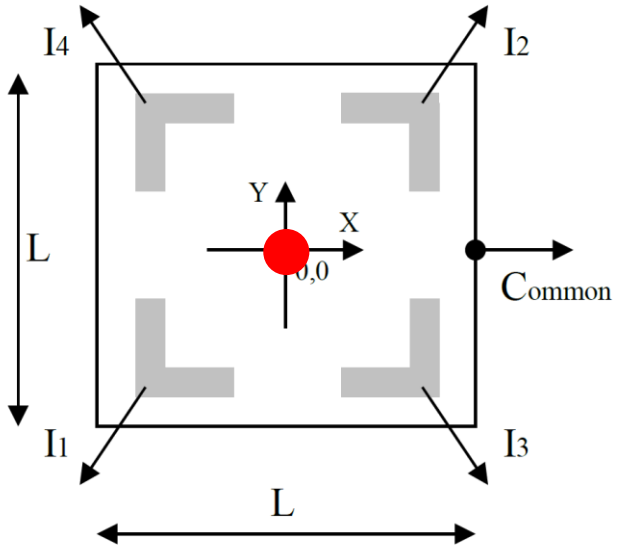
1/100th the
Thickness of Paper

1/200th the Diameter
of Human Hair

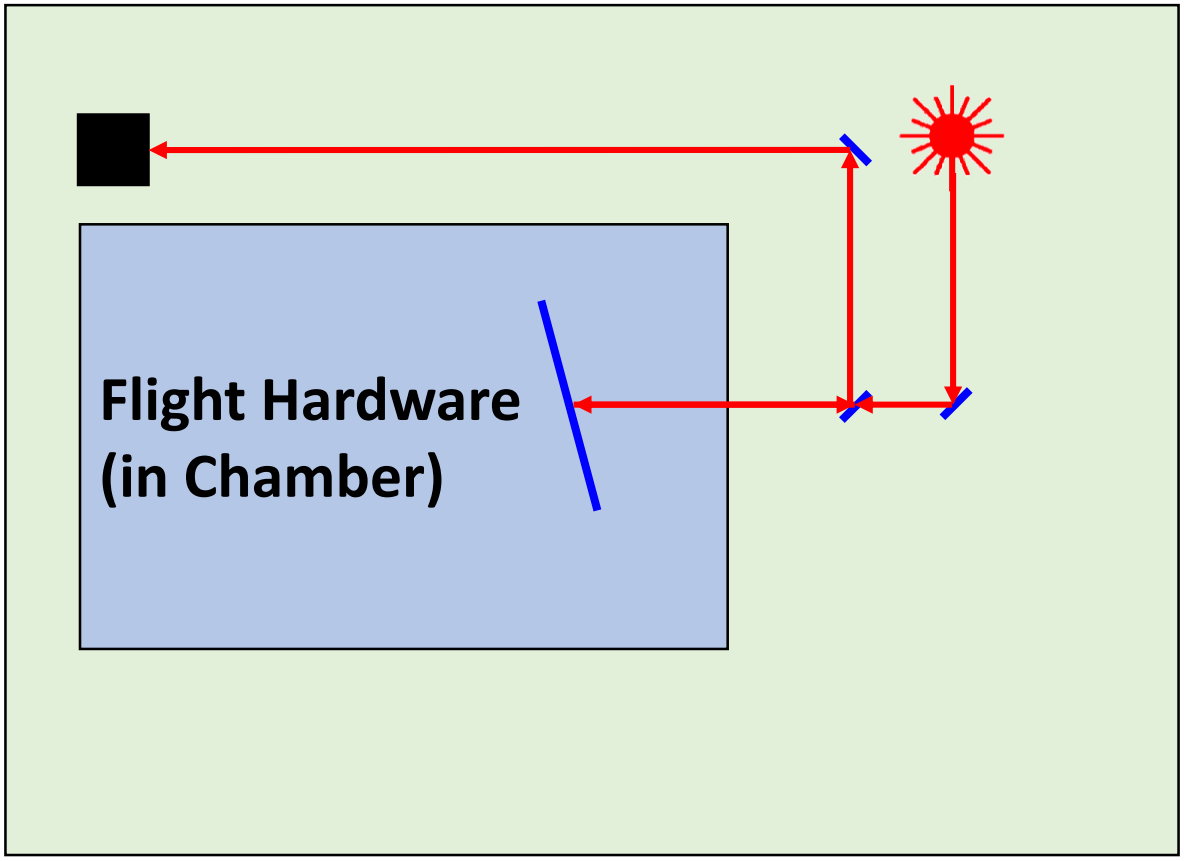


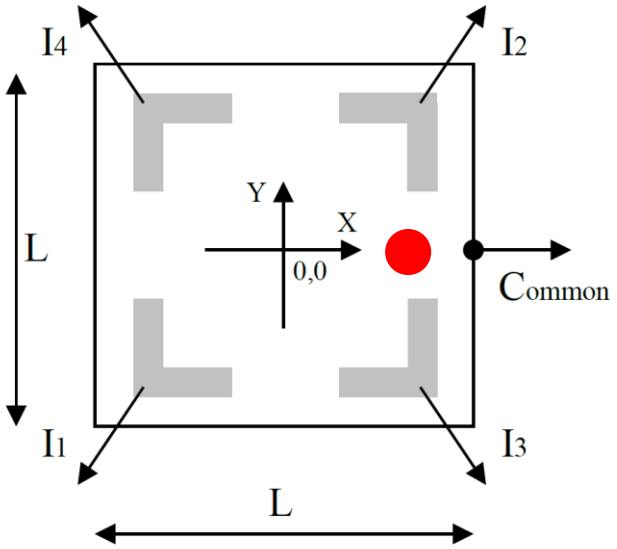
TVAC Optical Lever Measurement Setup



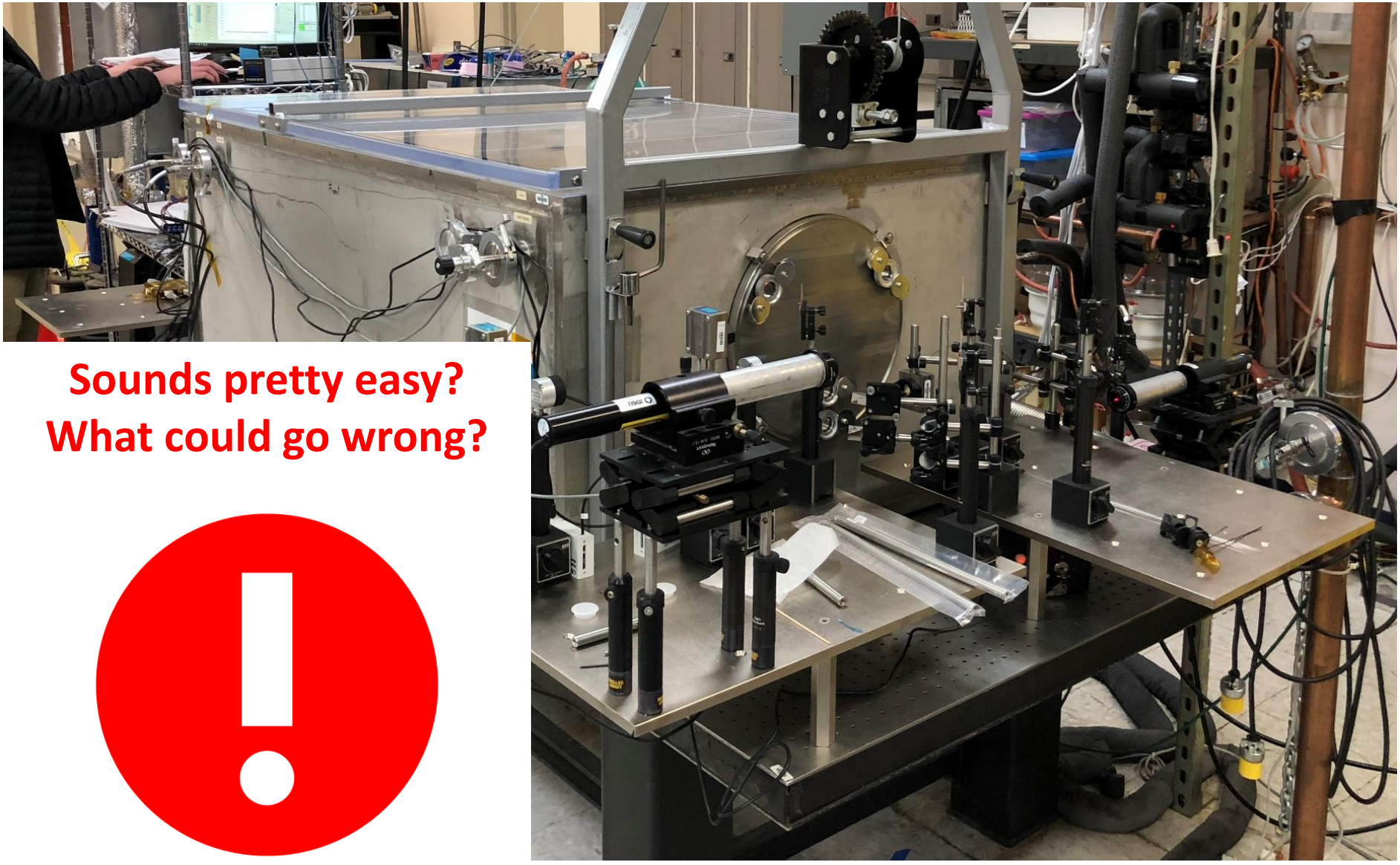


TVAC Optical Lever Measurement Setup





Optical Lever Measurement Setup Pictures

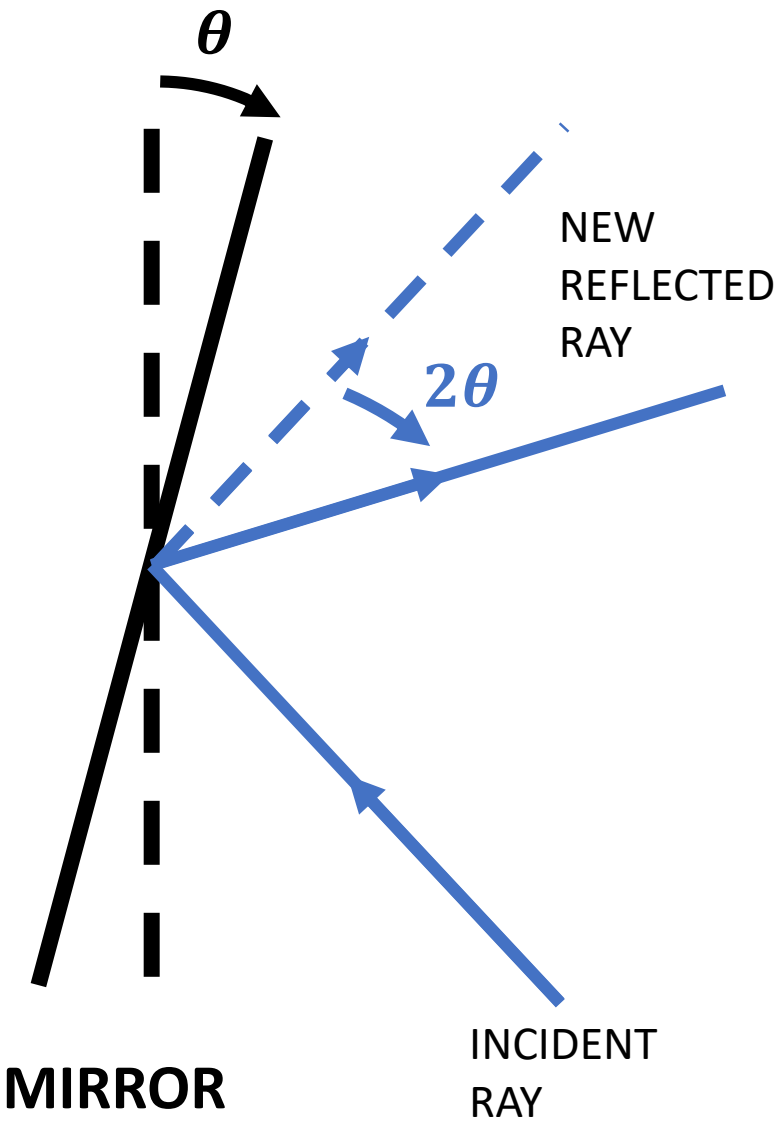


Sounds pretty easy?
What could go wrong?

Actuated Tip-Tilt Mirror Mount (Calibration Stage)

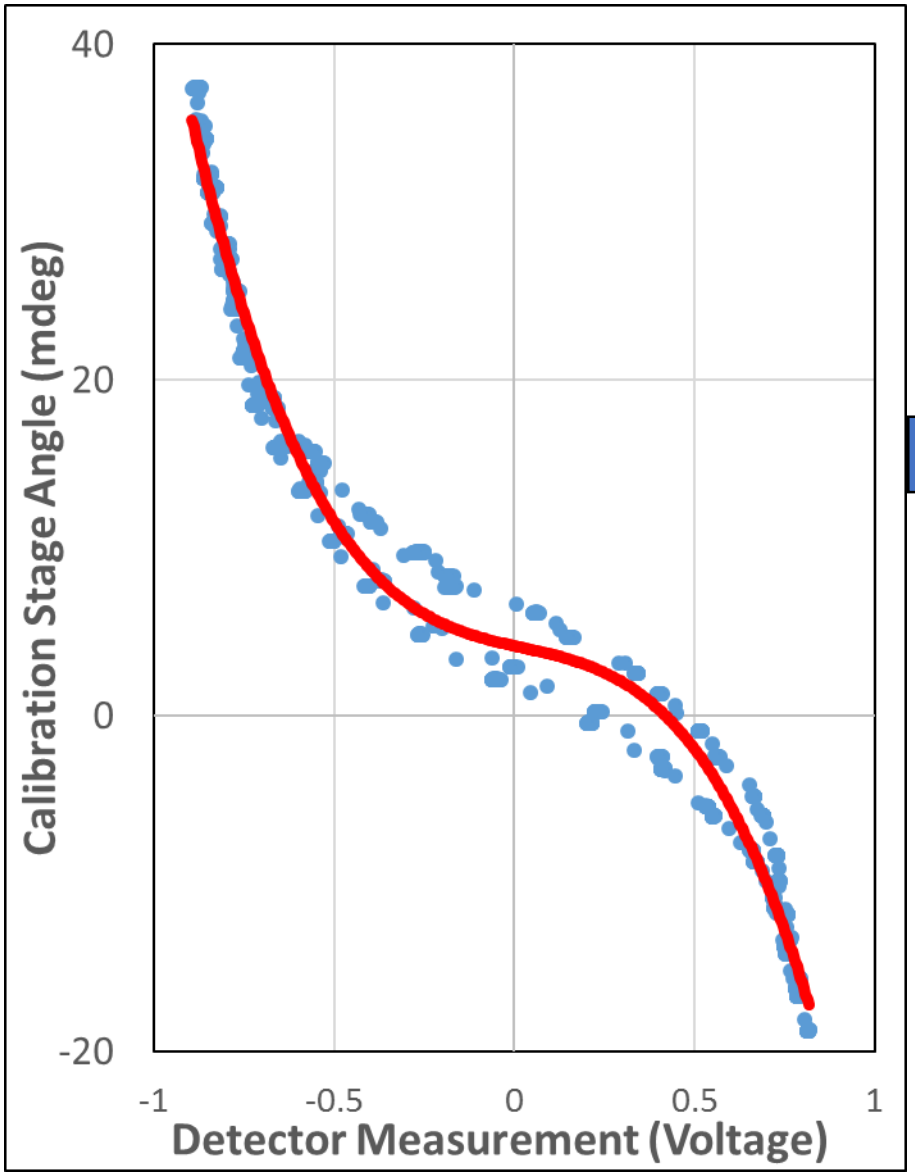
Motor Operated without Position Sensing

Closed-Loop Control with Encoder

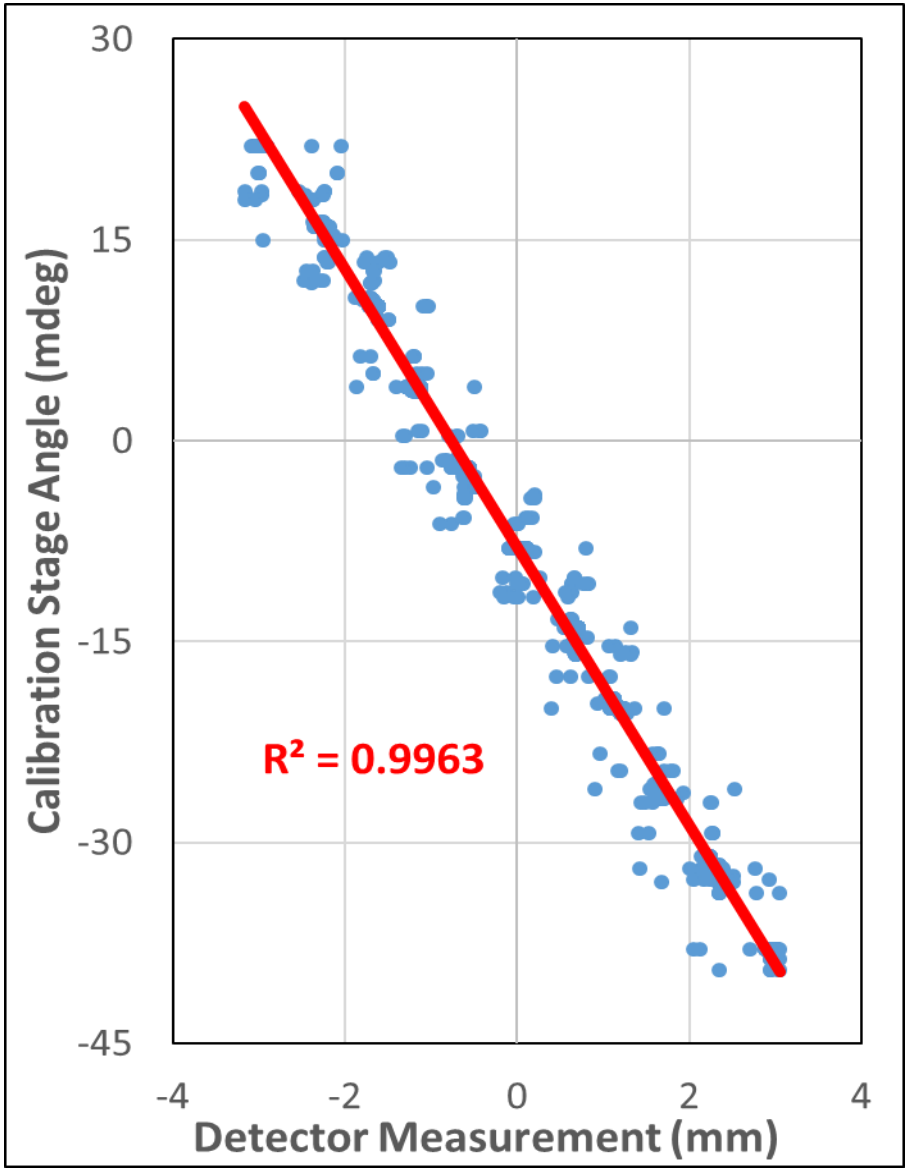


Calibrating the Beam Path Length for Optical Lever Setup (Non-Linear vs Linear Detectors)

Quadrant Diode Detector



Tetra-Lateral Diode Detector



Key Lessons Learned

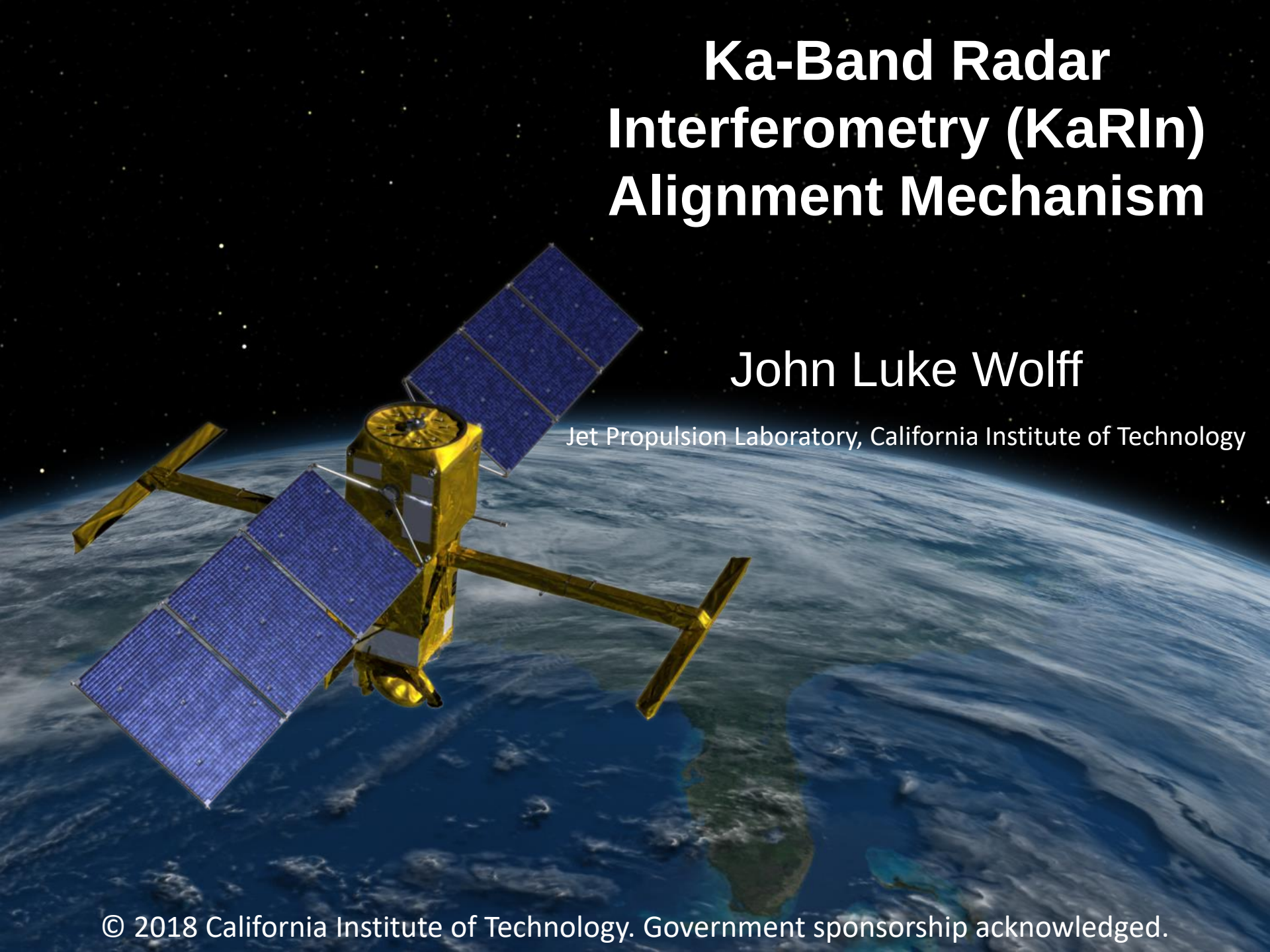
1. Angular motion requirements, based on sub-micrometer length changes, can be challenging to verify.

2. When working with small companies, understand the capabilities of the specific personnel working your task and recent history performing similar tasks.

3. Interfaces can drive not only design complexity but also test support and requirement verification complexity.

4. High performance hardware requires an even higher performance test apparatus to verify performance.

Ka-Band Radar Interferometry (KaRIn) Alignment Mechanism



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